

N73-27757
CR-13385-3



LMSC-A991396

30 JUNE 1973

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FINAL REPORT

**SHUTTLE CRYOGENICS
SUPPLY SYSTEM**

OPTIMIZATION STUDY

VOLUME V A-1

USERS MANUAL FOR MATH MODELS

CONTRACT NAS9-11330

Prepared for Manned Spacecraft Center.
by
Manned Space Programs, Space Systems Division

LOCKHEED MISSILES & SPACE COMPANY, INC.
A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION

FINAL REPORT
SHUTTLE CRYOGENIC SUPPLY SYSTEM
OPTIMIZATION STUDY

VOLUME VA-1
USERS MANUAL FOR MATH MODELS

Approved for Release by NSA on 09-11-2013 pursuant to E.O. 13526

FOREWORD

This Final Report provides the results obtained in the Shuttle Cryogenics Supply System Optimization Study, NAS 9-11330, performed by Lockheed Missiles & Space Company (LMSC) under contract to the National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas. The study was under the technical direction of Mr. T. L. Davies, Cryogenics Section of the Power Generation Branch, Propulsion and Power Division. Technical effort producing these results was performed in the period from October 1970 to June 1973.

The Final Report is published in eleven volumes*:

Volume I	- Executive Summary
Volumes I, III, and IV	- Technical Report
Volume VA-1 and VA-2 Math Model	- Users Manual
Volume VB-1, VB-2, VB-3, and VB-4 Math Model	- Programmer Manual
Volume VI	- Appendixes

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*The Table of Contents for all volumes appears in Volume I only. Section 12 in Volume III contains the List of References for Volumes I through IV.

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CONTENTS

Section		Page
	FOREWORD	iii
	ILLUSTRATIONS	vii
	TABLES	ix
1.0	INTRODUCTION	1
1.1	Program Description	1
1.1.1	Program Purpose	1
1.1.2	Program Structure	2
1.1.3	Program Operational Sequence	7
1.2	Input Data	34
1.2.1	Card Definition and Description	35
1.2.2	Card Format Description	59
1.2.3	Table Data Cards	85
1.2.4	Use of Program File and Data Files	92
1.2.5	Sample Input Data Deck Listing	97
1.2.6	Data Table, Deck List	97
1.3	Input Deck Setup	123
1.3.1	Single System Deck Setup	123
1.3.2	Multiple System Deck Setup	123
1.4	Math Model Program Machine Requirements	125
1.4.1	Segmented Overlay Procedure	125
1.5	Error Messages	131
1.5.1	Built-In Diagnostic Trace	131
1.5.2	Error Diagnostics	134
1.5.3	Preset Error Terminations	135
1.5.4	Errors in Reading Table Data	135
1.6	Program Restrictions	137
1.6.1	Program Analytical Range	137
1.6.2	Table Data Limits	137

Section	Page
1.7	Tape and Drum Assignments 138
1.7.1	Data Table Tape Preparation 138
1.7.2	Data Table Tape Utilization 139
1.7.3	Disc and Drum Utilization 140
2.0	MATH MODEL SAMPLE PROBLEM 141
2.1	The Problem Statement 141
2.2	Problem Outline – Data Acquisition 143
2.2.1	Sample System Performance and Component Data 143
2.3	Problem Data Deck 149
2.4	Problem Table Data Requirements 149
2.5	Problem Data Output 153
2.5.1	Output Description 153
3.0	REFERENCES 204

ILLUSTRATIONS

Figure		Page
1.1.2-1	Major Program Structure	3
1.1.2-2	Source Data Preparation Sequence	5
1.1.2-3	Program Input Requirements By Type of Data	6
1.1.3-1	Flow Chart for Subroutine CØNTRL	11
1.1.3-2	Flow Chart for Subroutine CØMPIL	13
1.1.3-3	Flow Chart for Subroutine CRYCØN	15
1.1.3-4	Flow Chart for ACPS Analysis	23
1.2.2.1	User I.D. Card - Case Title Card	67
1.2.2.2	Table Data Cards - File Usage	68
1.2.2.3	Alternate Table Data Input Cards	69
1.2.2.4	System Definition Input Card	71
1.2.2.5	Configuration Definition Data Cards	72
1.2.2.6	Duty Cycle Definition Data Cards	73
1.2.2.7	Engine Consumer Data Cards	74
1.2.2.8	APU Consumer Data Cards	75
1.2.2.9	Life Support Consumer Data Cards	76
1.2.2.10	Fuel Cell Consumer Data Cards	77
1.2.2.11	Tank Characterization Input Data Cards	78
1.2.2.12	Tank Geometry Input Data Cards	79
1.2.2.13	Accumulator Characterization Input Data Cards	80
1.2.2.14	Heat Exchanger Characterization Input Data Cards	81
1.2.2.15	Pump and Turbine Characterization Input Data Cards	82
1.2.2.16	Heat Source Characterization Data Input Data Cards	83
1.2.2.17	Motor Characterization Data Input Cards	84
1.2.3-1	Hydrogen Electrical Heater Heat Transfer Performance	86
1.2.3-2	Table Data Input Card Format	88
1.2.4-1	TCIMM Run Deck Setup to Use Program File and Data Table File	95
1.3.2-1	Multi-System Data Deck	124
1.5-1	Diagnostic Trace Illustration	133
2.1-1	ACPS Schematic Diagram	142

TABLES

Table		Page
1.1.2-1	Cryogen Systems - Component Similarity By Kind	8
1.1.3-1	Data Table Selection "ECHO"	10
1.1.3-2	CRYCØN Execution Sequence for ACPS Analysis	21
1.1.3-3	CRYCØN Execution Sequence for APU Subcritical System Analysis	23
1.1.3-4	CRYCØN Execution Sequence for APU Supercritical System Analysis	31
1.1.3-5	CRYCØN Execution Sequence for Life Support System Analysis	32
1.1.3-6	CRYCØN Execution Sequence for Fuel Cell System Analysis	33
1.2.2-1	Variable Names Employed for Control, Branching, and Switching Purposes	59
1.2.2-2	Configuration Variable Names and Definitions	62
1.2.3-1	Electrical Heat Exchanger - Heat Transfer Performance for Hydrogen Gas	87
1.2.3-2	Data Table Number 20 (Example)	91
1.2.5-1	ACPS Input Data Deck Listing	98
1.2.6-1	Listing of Data Tables	100
1.4.1-1	Math Model MAP Overlay	127
1.4.1-2	Loading Addresses for Segmented Overlay	129
1.4.1-3	Computer Drawn Overlay MAP	130
2.2-1	ACPS Duty Cycle	144
2.2-2	Configuration Data for ACPS - Oxygen Side	150
2.2-3	Configuration Data for ACPS - Hydrogen Side	151

Section 1.0

INTRODUCTION TO THE CRYOGENIC INTEGRATED MATH MODEL PROGRAM (TCIMM)

1.1 PROGRAM DESCRIPTION

The Integrated Math Model for Cryogenic Systems is a flexible, broadly applicable systems parametric analysis tool. The program will effectively accommodate systems of considerable complexity involving large numbers of performance dependent variables such as are found in the individual and integrated cryogen systems. Basically, the program logic structure pursues an orderly progression path through any given system in much the same fashion as is employed for manual systems analysis.

The system configuration schematic is converted to an alpha-numeric formatted configuration data table input starting with the cryogen consumer and identifying all components, such as lines, fittings, valves, etc., each in its proper order and ending with the cryogen supply source assembly. Then, for each of the constituent component assemblies, such as gas generators, turbo machinery, heat exchangers, accumulators, etc., the performance requirements are assembled in input data tabulations. Systems operating constraints and duty cycle definitions are further added as input data coded to the configuration operating sequence. Characteristic performance data over the range of temperatures, pressures and flow rates of interest for each of the functional component assemblies, is input to the program or table look-up data arrays to be called as needed in the analysis sequences. The use of table look-up data combined with closed-form solution analysis, where needed, permits the rapid computation of the desired parameters as the analysis proceeds through the system configuration.

The program will size the system to fit the operating demands and constraints and produces as output the component and system hardware size and weight, propellant (or reactant) weight, vented fluid weight, and such analytical information (i.e., computed performance values) as may be desired. The analytical results are displayed both as time dependent data tabulations and summary table data.

1.1.1 PROGRAM PURPOSE

The intended purpose of the program is to provide an analytical tool which permits rapid parametric evaluation of the various types of cryogenics spacecraft systems

currently under study in the national space program. The mathematical techniques built into the program provides the capability for in-depth analysis (combined with rapid problem solution) for the production of a larger quantity of soundly based trade-study data than normally would be obtained in hand calculations. Program flexibility in accommodating advanced systems resides in its modular type programming which permits program growth with simple addition of new subroutines and the addition of variables to existing common banks. Conversely, the program is easily dismantled if it is desired to limit analysis to only one or two systems and utilize a smaller computing machine.

In summary, the purpose of the program may be said to be that of providing an improved general analysis tool for cryogen technology applications.

1.1.2 PROGRAM STRUCTURE

The Integrated Math Model for Cryogenic Systems consists essentially of three major sections as illustrated in Figure 1.1.2-1. Within each of the major sections the structure is further broken into block subsections, each of which is reserved for specific functions of data management, data utilization or analytical data display.

1.1.2.1 PROGRAM INPUT DATA LOGIC

Of necessity, the program requires a rather large data bank capable of providing characteristic performance data for the wide variety of component assemblies found in typical cryogen systems.

Program data requirements for the Integrated Math Model are divided into two types. The first type consists of the "semi-permanent" data tables which the program employs to compute performance, weight, property, and other characteristics as a function of up to four variables per run.

The table data bank contains the necessary component performance characterization data for the system configurations to be considered, as well as the required cryogen properties data and required material properties data.

The "source data", as obtained, is verified as being authoritative, and is then processed into a formatted tabular array which specifies the table name, ID codes,

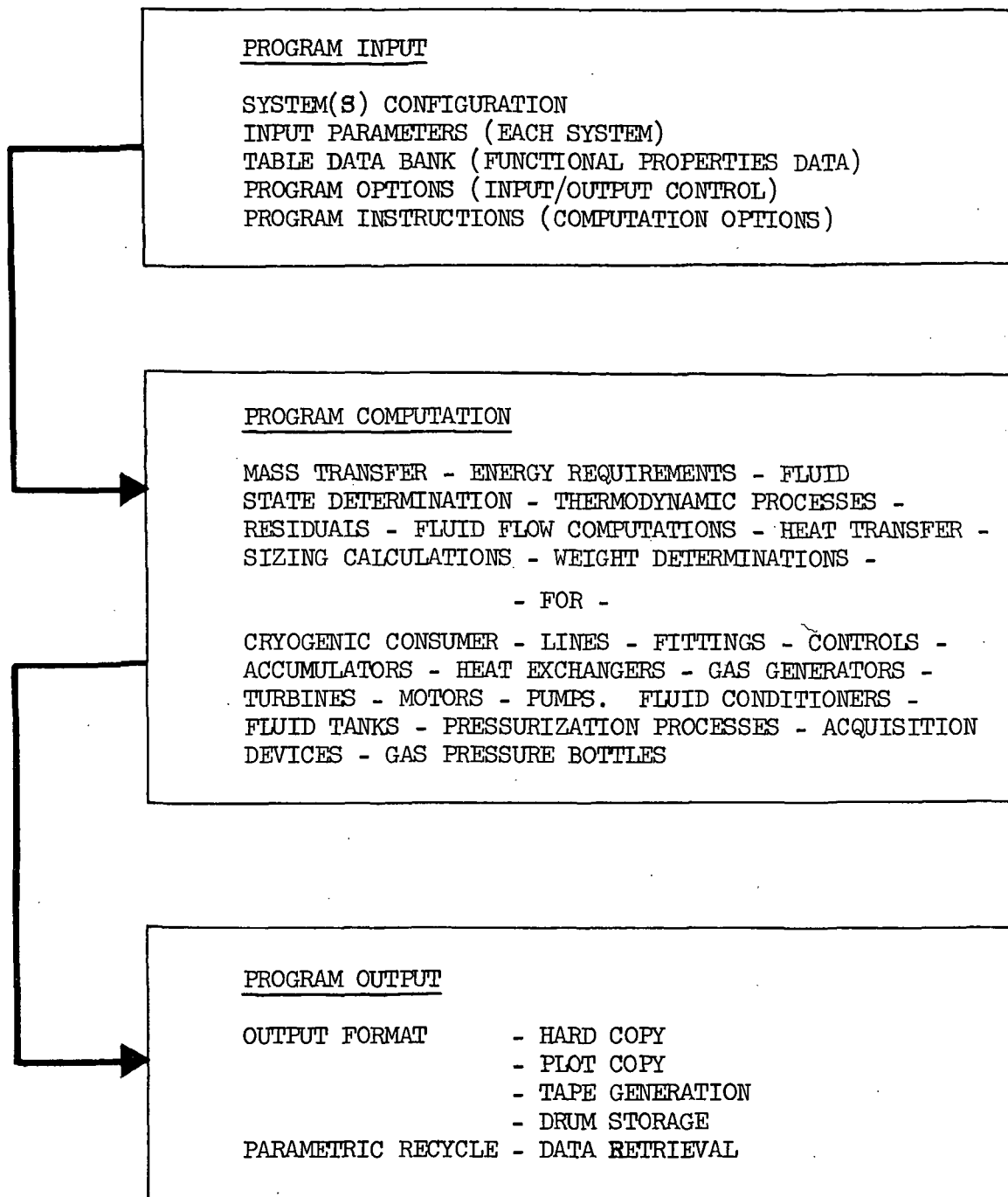


FIGURE 1.1.2-1 MAJOR PROGRAM STRUCTURE

the dependent variables, and the independent variables--in order of use. The tabulated array data is carefully ordered such that curve fitting routines can extrapolate data points with good accuracy and speed. The prepared data array is punched into data card decks and verified for correctness. The procedure is illustrated in Figure 1.1.2-2. All data tables are logged as to reference, source, date of data acquisition, and pertinent data limitations such as range of application, etc.

Since a large volume of table data can be required by the program, a unique data management set of subroutines is employed to retrieve any particular table and extract the required information with remarkably high speed and accuracy. Additionally, a machine plotted and/or printed tabulation "echo" of the tables can be requested for easy table input checking.

The program currently contains forty-six tables and currently will accommodate up to fifty tables for a total of 7000 words.

The second type of input data is "variable" and contains the variable input parameters which may be perturbed for parametric system studies. These data include duty cycle characteristics, configuration description, and operational requirements of the system being studied. The variable input values are printed out just prior to the system computed data output as a means of input verification.

The general program input data requirements by type of data and source is illustrated in Figure 1.1.2-3.

1.1.2.2 PROGRAM COMPUTATION LOGIC

In order for the Integrated Math Model to accommodate the possible range of cryogenic systems likely to be considered and perform as a general systems analysis tool, the following three premises are established:

- (1) Any logical combination of supply tanks, lines, fittings, valves, regulators, heat exchangers, gas generators, pumps, accumulators, and "cryogen-consumer" components can be specified as a system configuration point.
- (2) The "cryogen-consumer" component may be any of the components being supplied with cryogenic fluids.

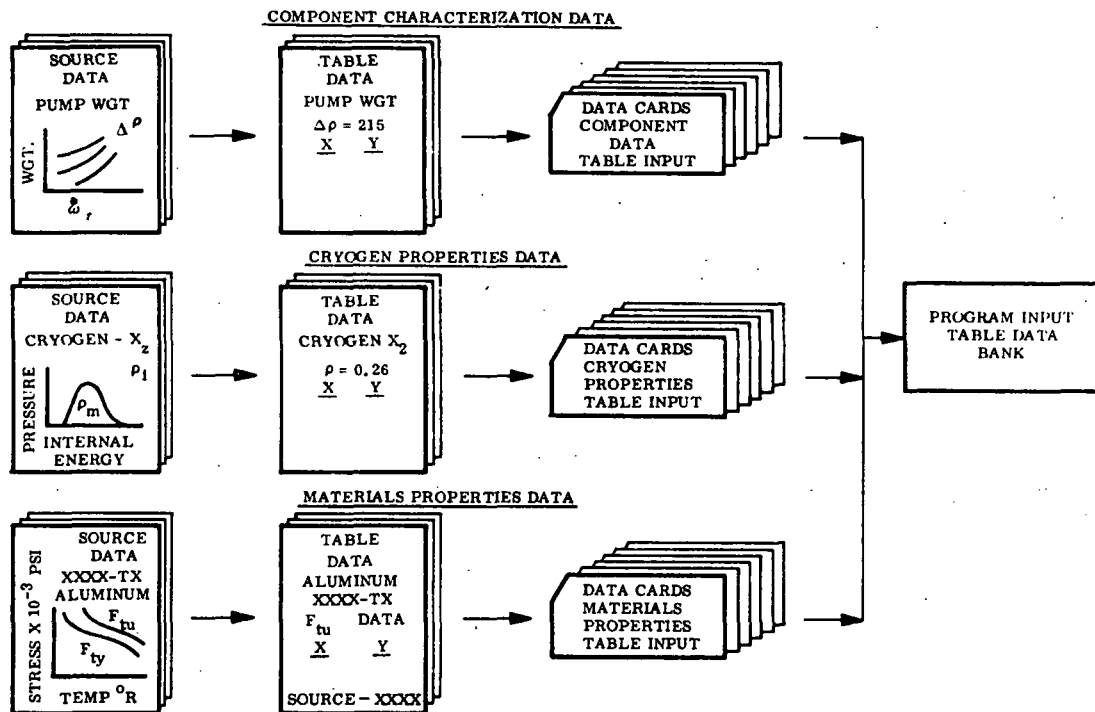


FIGURE 1.1.2-2 SOURCE DATA PREPARATION SEQUENCE

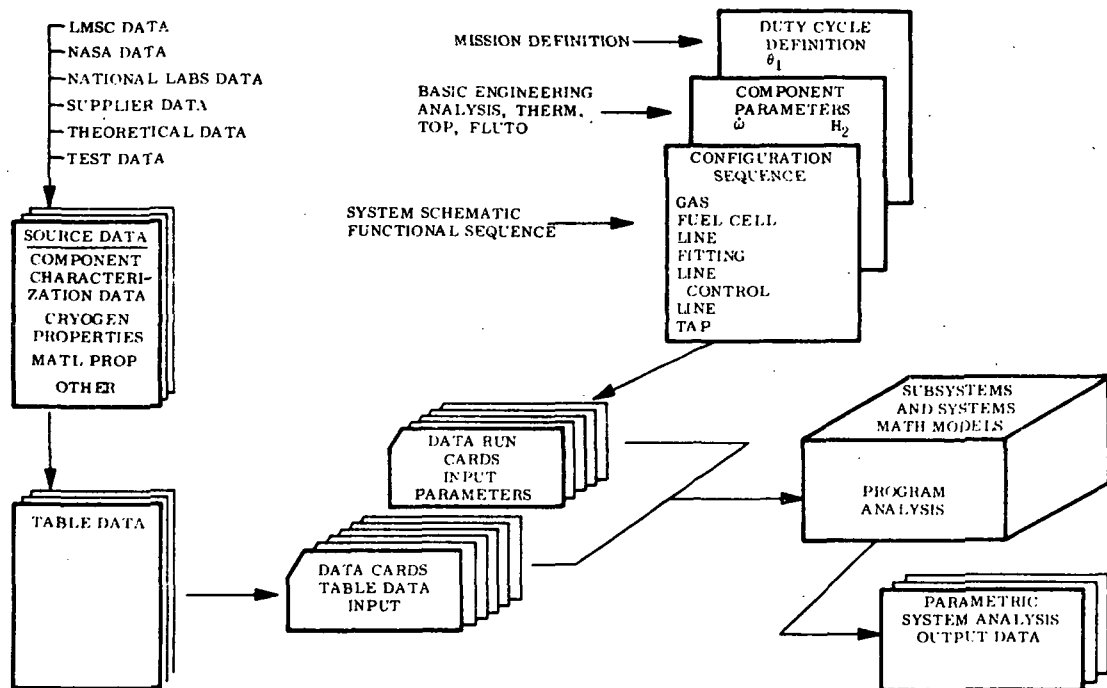


FIGURE 1.1.2-3 PROGRAM INPUT REQUIREMENTS BY TYPE OF DATA

- (3) An integrated cryogenic system may contain a number of similar and/or different cryogen subsystems to be fed from a common cryogen supply source.

Although these premises appear to force the generation of a very large program, an examination of the six basic individual cryogen system concepts reveals a marked similarity and commonality of components by kind. Table 1.1.2-1 illustrates adequately the fact that there are less than twenty-five kinds of major component assemblies to be considered, additionally, the temperatures, pressures, and flow rates are for the most part within reasonable range spans, thus further reducing the quantity of data to be manipulated.

1.1.3 PROGRAM OPERATIONAL SEQUENCE

The program capability for accommodating a number of different kinds of systems analysis, derives from the use of built-in sequencing indices. The indices are stored as data statements in subroutine STØDTA, and are readily available to a programmer or knowledgeable program-user for restructuring, if necessary. The indices are used by the various system analysis subprograms to direct the analysis from one set of procedural steps to the next in a preprogrammed manner. The details of the program operational sequence for the various systems to be analyzed are explained in the following subparagraphs.

1.1.3.1 PROGRAM INITIATION AND CONTROL

Program initiation is accomplished through by the driver subroutine CØNTRL. This subroutine initializes the data storage subroutines and reads the first card of the input data deck for the user's name and program title. Following this a call to subroutine INTAB reads in table data deck (or file) to storage. As a check on the correctness of the data table input, subroutine INTAB causes an "echo" printout of the selected table numbers to be printed for visual reference. A typical "echo" print is illustrated in Table 1.1.3-1. Note that the "echo" also permits verification of the number of words in any given table, thus aiding the user in troubleshooting incomplete table entries. CØNTRL then reads in the name and type of system to be evaluated. This is followed by a call to subroutine CØMPIL which reads into core the cryogen system input data deck containing the system duty cycle, configuration sequence, and pertinent system and component parametric information.

COMPONENT LIST	ACPS		APU		FUEL CELL		EC/LSS		OMS	
	SUBCR	SUPCR	SUBCR	SUPCR	SUBCR	SUPCR	SUBCR	SUPCR	P.A.E.	P.A.T.
ENGINE (MAIN)									•	•
ENGINE (AUXILIARY)	•	•								
TURBINE - GENERATOR			•	•						
FUEL CELL					•	•				
CABIN ATMOSPHERE							•	•		
ENVIRONMENT CONTROL							•	•		
LINES	•	•	•	•	•	•	•	•	•	•
FITTINGS	•	•	•	•	•	•	•	•	•	•
VALVES	•	•	•	•	•	•	•	•	•	•
REGULATORS	•	•	•	•	•	•	•	•		
ACCUMULATORS	•	•	•	•						
HEAT EXCHANGERS	•	•	•	•	•	•	•	•		
HEAT SOURCES			•	•	•	•	•	•		
GAS GENERATORS	•	•	•	•						
TURBINES	•									•
MOTORS			•							
PUMPS	•		•							•
TANKAGE	•	•	•	•	•	•	•	•		
THERMAL CONDITIONING UNIT	•		•						•	•
PRESSURE CONTROL	•	•	•	•		•	•	•	•	•
ACQUISITION	•		•						•	•
GAS STORAGE			•						•	•
CIRCULATION PUMPS				•		•				

TABLE 1.1.2-1 CRYOGEN SYSTEMS - COMPONENT SIMILARITY BY KIND

Subroutine CØNTRL next calls subroutine CRYCØN to process the calculations required for the system being considered. Completion of the required calculations causes program control to return from CRYCØN to CØNTRL. Subroutine CØNTRL then tests to see if additional system data decks are to be read in, if so, it does and repeats the cycle; if not, CØNTRL calls EXIT and terminates the run.

Brief flow-charts for CØNTRL, CØMPIL, and CRYCØN are presented in Figure 1.1.3-1, -2, and -3.

TABLE 1.1.3-1
DATA TABLE SELECTION "ECHO"

TABLE NUMBER	TITLE OF TABLE	NUMBER OF DIMENSIONS	NUMBER OF SURTABLES	NUMBER OF WORDS
1	RCS-THRUSTER WEIGHT	4	6	122
2	RCS-VAC. SP. IMPULSE	3	3	68
3	SPEC.HT/LB OF O2 REMOVED	3	5	206
4	SPEC.HT/LB OF H2 REMOVED	3	5	184
5	TEMP. /LB. OF O2 REMOVED	3	5	184
6	TEMP. /LB. OF H2 REMOVED	3	5	192
7	RR/ VS PGG,M/R,PAMB,PCHP	5	12	95
8	KK VS PGG,M/R,PAMB,PCHP	5	12	95
9	ONS ENGINE WEIGHT	3	3	50
10	ONS VAC. SP. IMPULSE	3	3	68
11	HEX HOT GAS FLOW - LO2	5	24	133
12	HEX HOT GAS FLOW - LH2	5	12	71
13	GAS GENERATOR WEIGHT	4	10	220
14	LO2 TRANSFER PUMP WEIGHT	5	8	130
15	LH2 TRANSFER PUMP WEIGHT	5	8	138
16	MOTOR WEIGHT	3	5	120
17	VAC.JAC.DIA.VS.WEIGHT	2	1	34
18	PHI - HYDROGEN	3	5	172
19	TEMP. OF N2 VS RHO F(P)	3	5	180
20	HT.XFER.COEF.-H2	3	4	106
21	HT.XFER.COEF.-O2-N2	3	4	138
22	FTU OF 321/347 ST.STEEL	2	1	32
23	FTU OF 2219-T87 ALUM.	2	1	36
24	FTU OF 6061-T6 ALUMINUM	2	1	30
25	FTU OF INCONEL-718	2	1	30
26	FTU OF TI-6AL-4V	2	1	30
27	HEAD COEFFICIENT VS NS	2	1	34
28	ADIABATIC EFF. VS NS	2	1	44
29	EFFIC. QUOT.VS IMP. DIAM	2	1	46
30	BASE LINE STAGE WT VS DI	2	1	28
31	SATURATED STEAM. T.VS P.	2	1	46
32	SP.HT. OF O-H COMB.PROD.	3	4	114
33	OXYGEN INTERNAL ENERGY	3	5	166
34	HYDROGEN INTERNAL ENERGY	3	5	216
35	OXYGEN INTERNAL ENERGY	3	5	142
36	OXYGEN VAPOR PRESSURE	3	5	166
37	HYDROGEN VAPOR PRESSURE	3	5	216
38	OXYGEN VAPOR PRESSURE	3	5	142
39	ENTHALPY OF LO2	2	1	46
40	ENTHALPY OF LH2	2	1	24
41	ENTHALPY OF HELIUM	3	5	142
42	OXYGEN ENTHALPY (GAS)	3	5	98
43	HYDROGEN ENTHALPY (GAS)	3	5	122
44	BETA FACTOR	2	1	28
45	SIGMA-DELTAP FOR HEXELC	3	5	172
46	BETA VALUES FOR H2	3	5	168

TOTAL TABLE STORAGE = 5024

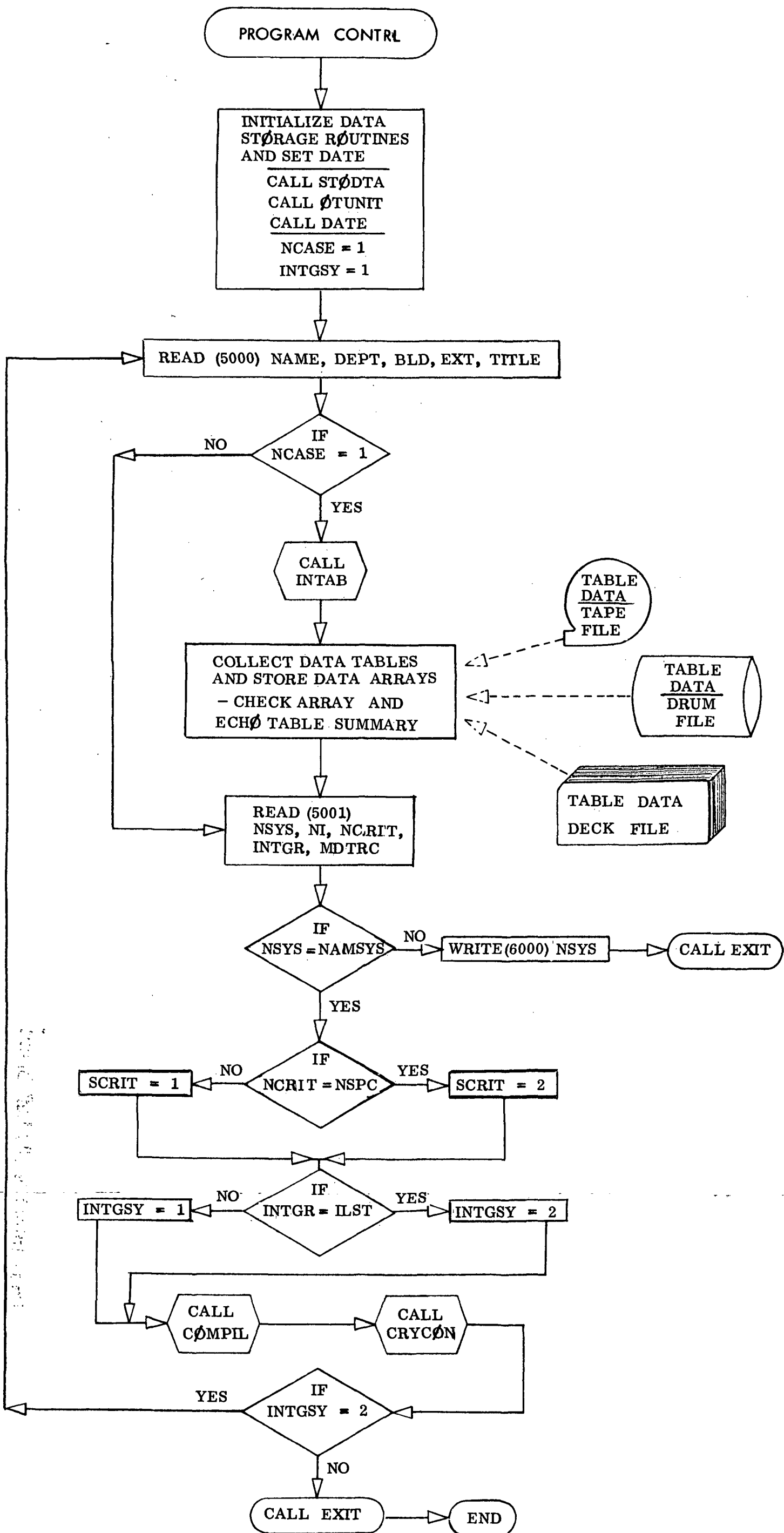


Fig. 1.1.3-1 Flow Chart For Subroutine CØNTRØL

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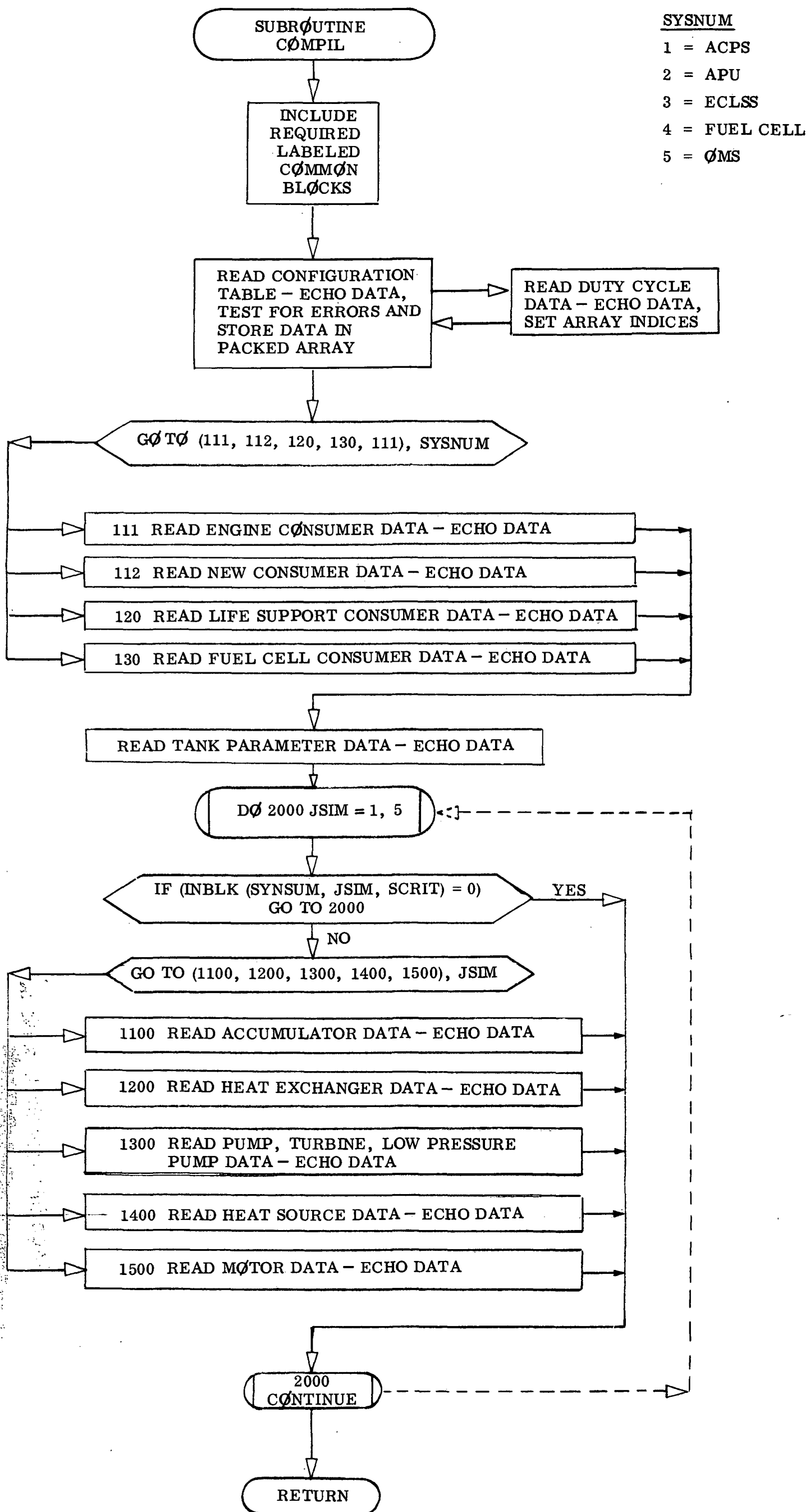


Fig. 1.1.3-2 Flow Chart for Subroutine
COMPIL (Simplified)

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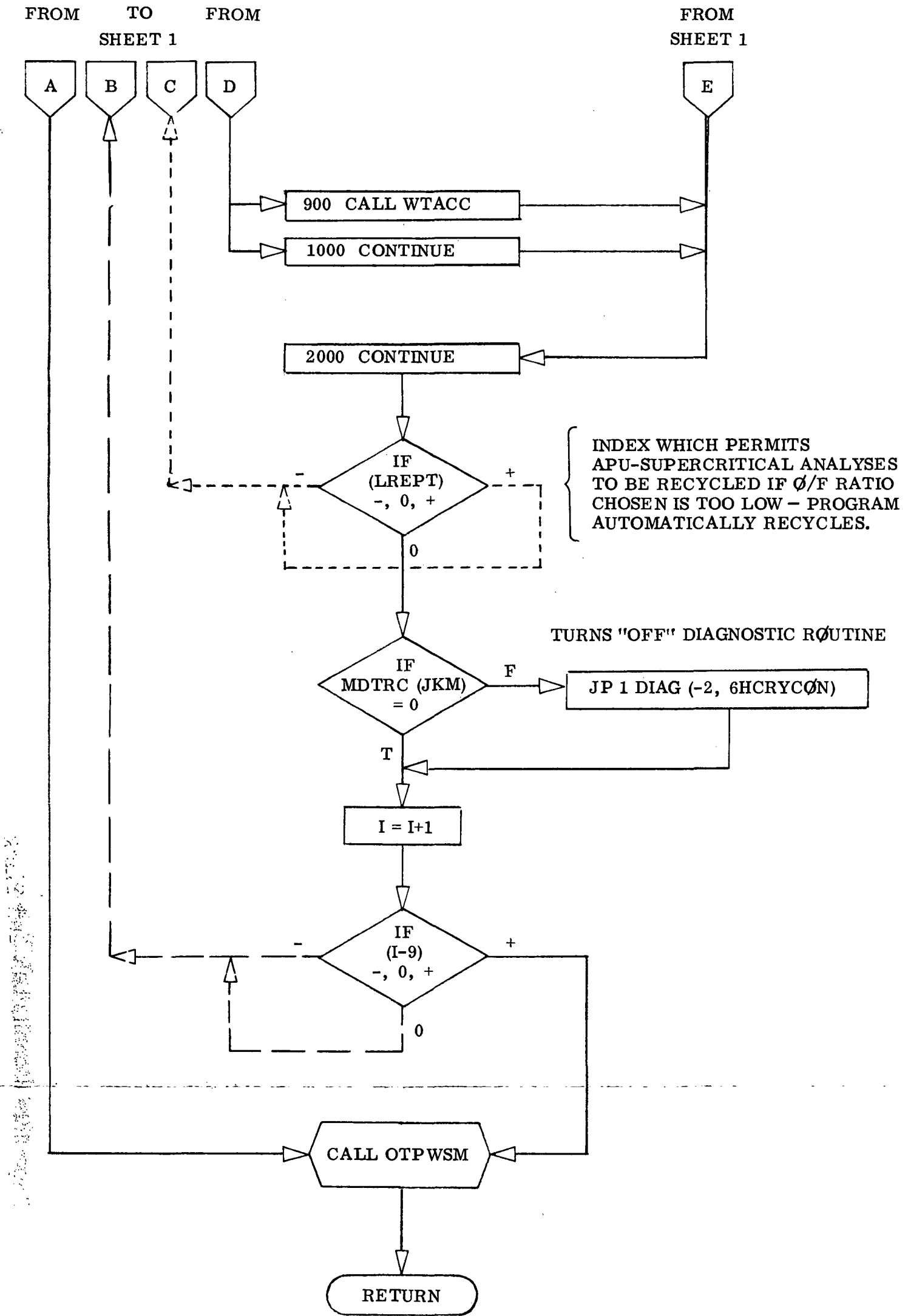


Fig. 1.1.3-3 Flow Chart for Subroutine CRYCØN (Sheet-2)

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1.1.3.2 Program Sequencing Subroutine. The mechanism for controlling the analysis sequencing is set up in Subroutine CRYCØN. This subroutine performs the major branching functions of calling in the various subprograms needed for each specific system type analysis. Key variables used by CRYCØN to effect this control over the analysis sequencing are SYSNUM and SCRIT. For each cryogen system (and system kind) there exists a preprogrammed set of induces stored on a data statement (KSUBC [SYSNUM, I]) which defines the order in which the major analytical subroutines will be called. This set of indices are used in CRYCØN for sequencing purposes.

1.1.3.2.1 Program Calculations Sequence. The initiation of specific system calculations occurs in Subroutine CRYCØN. For any of the five cryogen systems, CRYCØN will obtain from labeled common CCNTRL, the values for SYSNUM and SCRIT. This permits access to the indices stored in the preprogrammed set of data statements KSUBC (SYSNUM, I). The branching index JKM (see Fig. 1.1.3-3) then can assume the value of each stored sequencing index in a given KSUBC data statement as CRYCØN cycles through its "I" loop. Concurrently, as each JKM index is picked up, CRYCØN tests to see if the specified subprogram requires a "user signalled" diagnostic switch to be turned "ON" or left "OFF." This is an especially useful feature when debugging changes to subprogram coding. Values for MDTRC, the diagnostic indices, are entered by the user in the system run data deck (see Section 1.2). The KSUBC data statements are physically located in Subroutine STODTA and are available through labeled common CCNTRL via an INCLUDE statement.

The index "K" employed in CRYCØN is used to indicate initial or final conditions for subroutine TSIZEI (K). For the specific requirements of an Auxiliary Power System analysis (APU), the value of "K" can only be set equal to two (2). For all other system analysis "K" is set equal to one (1) the first time called and set equal to two (2) the second time called.

The index "LREPT" is employed, by CRYCØN, only when processing a super-critical APU system. Its use permits the recycling (starting over again) of subroutine APUSUP when that subprogram determines that the fuel mixture ratio (O/F) input value is too low and yields impossible temperature values. At that point the subprogram incrementally raises the O/F ratio and reruns the analysis. If three attempts fail, the subprogram quits and terminates the analysis.

The manner in which the sequential execution of CRYCØN can vary is explained in the subsections which follow.

1.1.3.2.2 ACPS - OMS Systems Calculation Sequence. If, for example, a sub-critical cryogenic reaction control system (ACPS) had been chosen for analysis, the following would be the sequence of events executed by subroutine CRYCØN. The values assigned to SYSNUM, SCRIT, and KSUBC (SYSNUM, I) would be:

SYSNUM = 1	(For ACPS)
SCRIT = 1	(Subcritical System)
KSUBC (1, I)	(KSUBC for ACPS)

and the preprogrammed Data Statement to be used would be:

DATA (KSUBC [1, I], I = 1, NBR SR)/6, 4, 10, 9, 8, 1, 10, 11, 2/

where "NBR SR" is defined as 9 in PDP-CCNTRL.

There are, therefore, nine subprograms to be called in the reaction control system analysis.

Referring to the CRYCØN Flow Chart (Fig. 1.1.3-3), note that statement 10 sets I = 1 for the first pass in the calculation loop. Statement 20 then sets JKM = KSUBC (SYSNUM, I), or, literally equal to KSUBC (1, I) which is the first of the nine values defined in the data statement body. Thus JKM = 6 in the first loop pass. Statement 50 is a "computed" GO TO statement which in this instance literally says

GO TO the JKM (6th) value within the parenthesis, or GO TO Statement 500, which calls subroutine CØNSUM. Thus, the order of subprogram execution, in sequence, by subroutine CRYCØN for a reaction control system analysis would be as shown in the table below:

Table 1.1.3-2

CRYCØN EXECUTION SEQUENCE FOR ACPS ANALYSIS

<u>Loop Pass</u>	<u>JKM Value</u>	<u>GØ TØ Statement</u>	<u>Subprogram Called</u>
1	6	500	CØNSUM
2	4	400	CMPCAL
3	10	800	TSIZEI(1)
4	9	700	TANK
5	8	600	LIQRES
6	1	100	ACCRES
7	10	800	TSIZEI(2)
8	11	900	WTACC
9	2	200	ACQWT

The above table holds true for an orbit maneuvering system (subcritical cryogen) as well, since the only significant differences are larger engines and fewer, but larger, component parts.

Upon completion of nine loop passes through CRYCON, accomplishing all of the calculations required by the respective subprograms, the final step is a call to subroutine OTPWSM which extracts from the labeled common storage, the values needed for a system weight summary and outputs these data in a formatted weight summary table. Program control returns to subroutine CONTRL for either execution of a second case (system analysis) or termination. A general flow chart for a typical reaction control system analysis is presented in Figure 1.1.3-4.

1.1.3.2.3 APU System Calculations Sequence. For the Auxiliary Power System analysis, two operating system types are possible; a subcritical cryogen fluid supply subsystem and a supercritical cryogen fluid supply subsystem.

It is therefore necessary to provide a means of altering the preprogrammed values to accommodate both cryogen fluid supply subsystems. This is accomplished by pre-programming KSUBC (2,I) for the more likely supercritical fluids case, and modifying the data statement when considering the subcritical cryogen fluid supply subsystem. This data statement adjustment is automatically taken care of in subroutine CRYCON DO6 loop as shown in the Flow Chart (Ref. Fig. 1.1.3-4). The DO6 loop will reverse the second and third values of the data stored as KSUBC(2,I) depending upon the value assigned to SCRIT. JAPUS (SCRIT, I) is the variable accomplishing the switch in value. The data statements defining JAPUS are stored in subroutine STODTA.

Subcritical Analysis: For an APU system requiring a subcritical cryogen fluid supply subsystem, the values assigned, via input, to the variables SYSNUM, SCRIT and KSUBC (SYSNUM, I) would be

SYSNUM = 2	(For APU)
SCRIT = 1	(For Sub critical)

and KSUBC(2,I)

The preprogrammed data statement stored in core is
 KSUBC(2 I) I = 1,9)/6 3 4 10 11 2 0 0 0/ which is actually the sequence for a

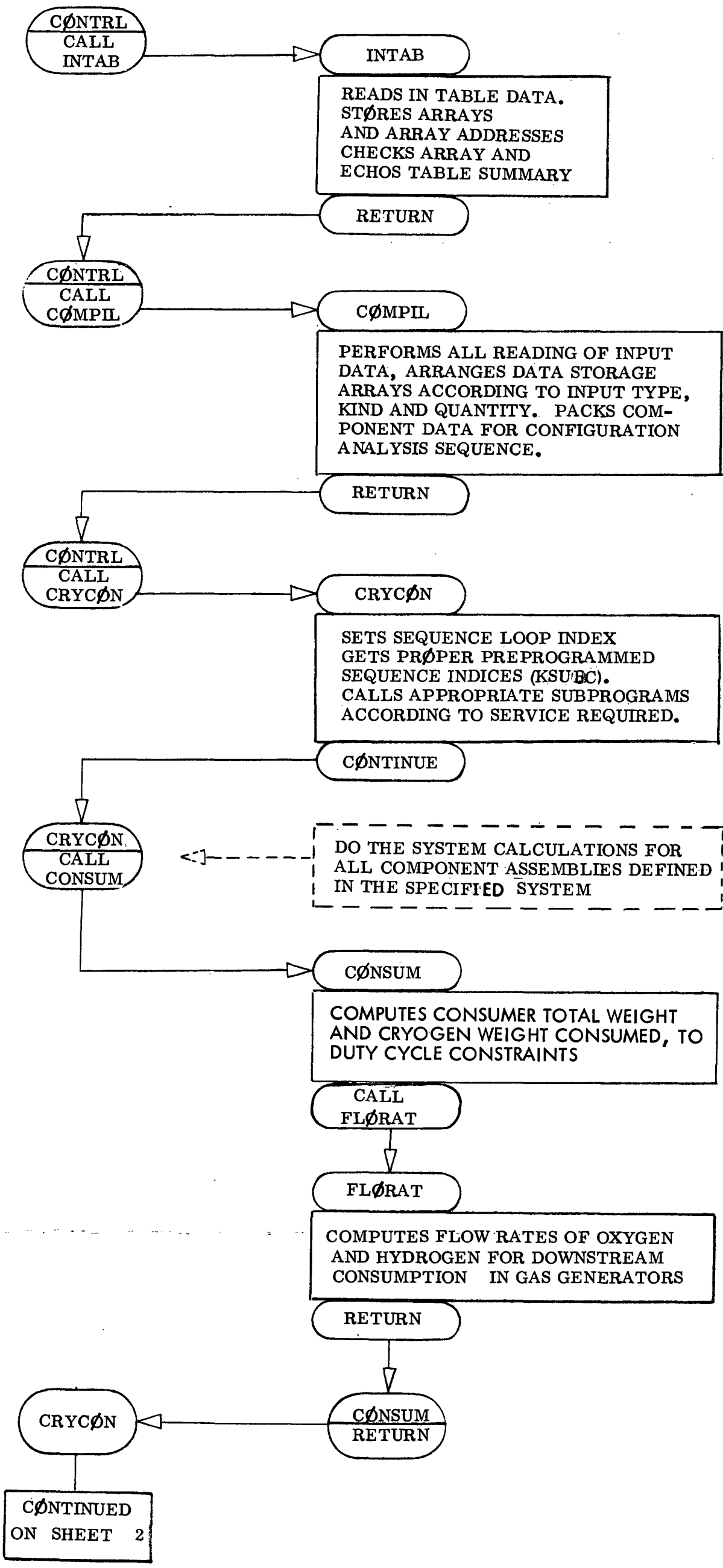


Fig. 1.1.3-4 General FLOW Chart For ACPS-OMS System Analysis (Sheet -1)

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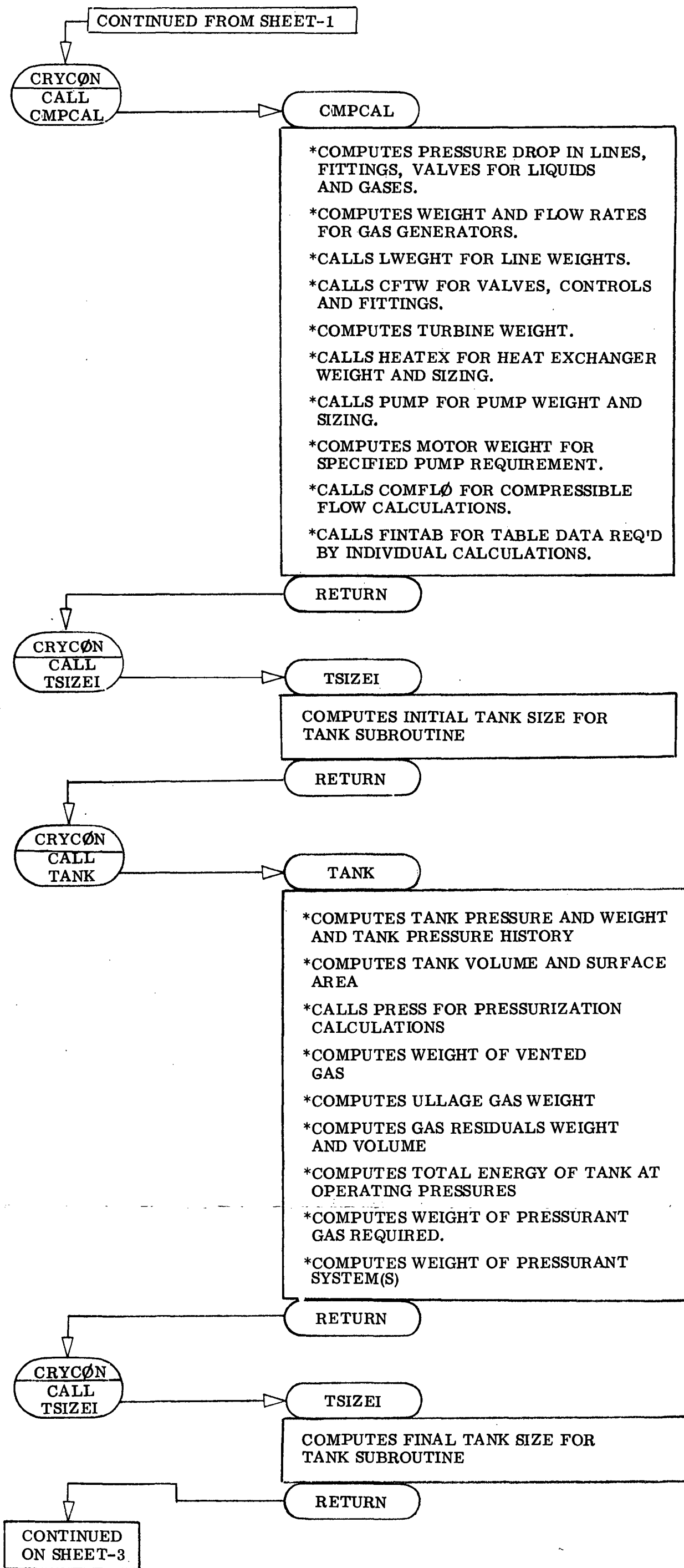


Fig. 1.1.3-4 General Flow Chart for ACAS-QMS System Analyses (Sheet-2)

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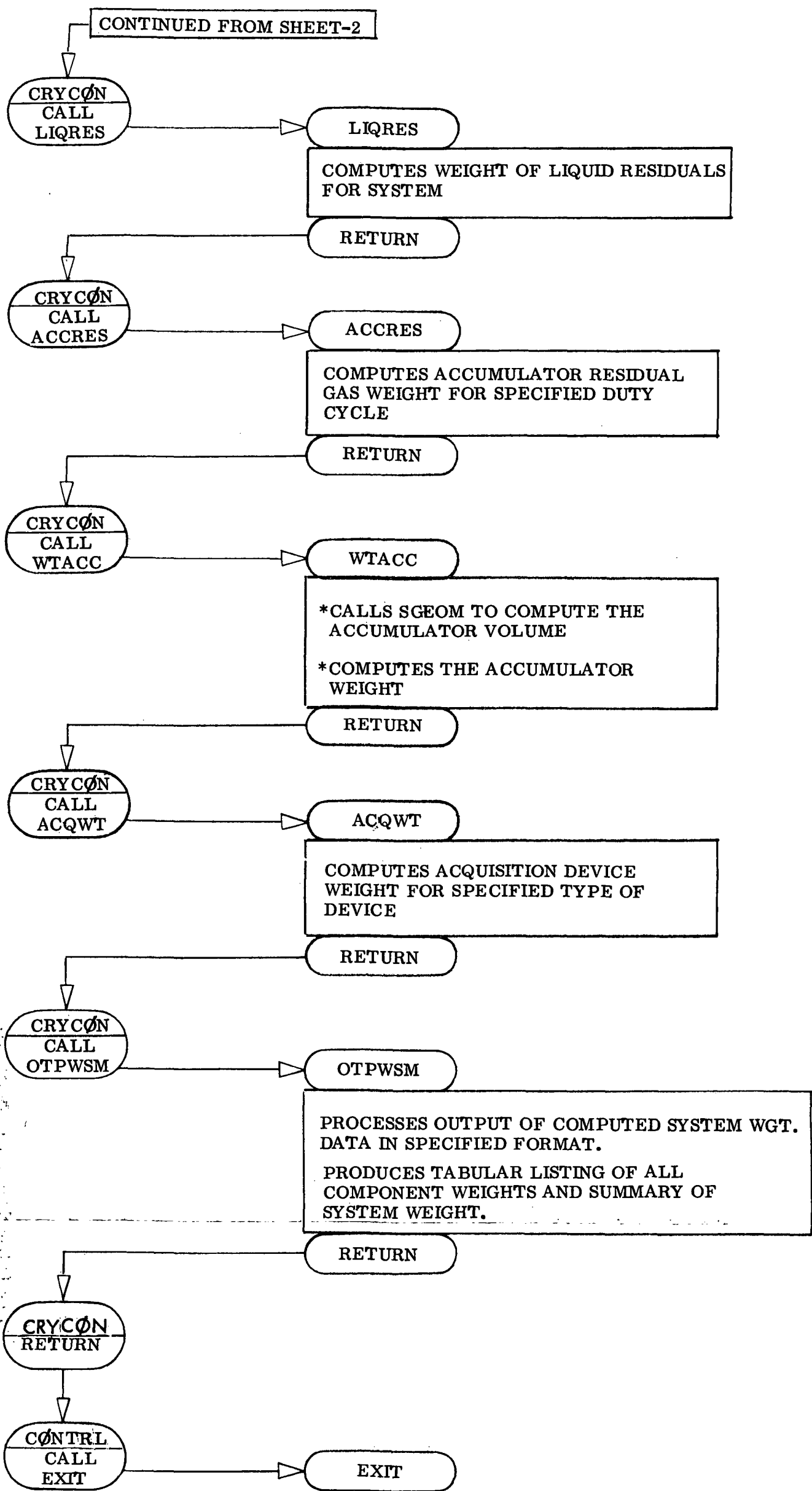


Fig. 1.1.3-4 General Flow Chart For ACPs-OMS
System Analysis (Sheet 3)

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supercritical subsystem. Therefore, the first action by CRYCØN is to reset the second and third values in a two-step loop as follows:

1st; KSUBC(2,2) = JAPUS(1,1) = 4

2nd; KSUBC(2,3) = JAPUS(1,2) = 3

and the reversed data statement becomes:

KSUBC(2,I),F = 1,9/6, 4, 3, 10, 11, 2, 0, 0, 0/

Note that only six subprograms are called in an APU analysis. The order of subprogram execution, in sequence, is presented in the following table.

Table 1.1.3-3

CRYCON EXECUTION SEQUENCE FOR AN APU SUBCRITICAL SYSTEM ANALYSIS

<u>Loop Pass</u>	<u>JKM Value</u>	<u>GØ TØ Statement</u>	<u>Subprogram Called</u>
1	6	500	CØNSUM
2	4	400	CMPCAL
3	3	300	APUSUB
4	10	800	TSIZEI(2)
5	11	900	WTACC
6	2	200	ACQWT
7	0	2200	Terminates Loop

Upon leaving the sequence loop subroutine CRYCON calls subroutine OTPWSM to output the component and system weight summary. Program execution returns to subroutine CONTRL which checks to see if another case (same system, or, new one) is to be run, or if program termination is in order.

Super-critical Analysis:

For an APU system requiring a super-critical cryogen fluid supply subsystem, the input values assigned to the variables SYSNUM, SCRIT and KSUBC (SYSNUM, I) would be:

SYSNUM = 2 (For APU)
 SCRIT = 2 (For Super-critical)

and KSUBC(2, I)

Assuming, for example, that the supercritical case is run as the second case in a multi-case run (not necessarily so) the preprogrammed data statement in core would still be, KSUBC(2, I), I = 1, 9)/6, 4, 3, 10, 11, 2, 0, 0, 0/. The first activity in CRYCON, since SYSNUM = 2, will be to reset the second and third value of the KSUBC data in a two-step loop as follows: (SCRIT = 2)

1st KSUBC(2,2) = 3

2nd KSUBC(2,3) = 4

and the revised data statement becomes;

KSUBC(2,I), I = 1, 9)/6, 3, 4, 10, 11, 2, 0, 0, 0/.

The order of sub-program execution, in sequence, is presented in the following table:

Table 1.1.3-4

**CRYCØN EXECUTION SEQUENCE FOR AN APU SUPERCRITICAL
SYSTEM ANALYSIS**

<u>Loop Pass</u>	<u>JKM Value</u>	<u>GØ TØ Statement</u>	<u>Subprogram Called</u>
1	6	500	CØNSUM
2	3	300	APUSUP
3	4	400	CMPCAL
4	10	800	TSIZEI(2)
5	11	900	WTACC
6	2	200	ACQWT
7	0	2200	Terminates Loop

Upon leaving the sequence loop CRYCØN calls subroutine ØTPWSM to output the component and system weight summary, and then return program execution to subroutine CØNTRL.

1.1.3.2.4 Life Support System Calculation Sequence. For the Life Support System analysis, the cryogen fluid supply subsystem is by definition a supercritical subsystem with a relatively simple and straightforward plumbing structure. It is also unique among the other systems, in that the cryogen fluids employed are oxygen and nitrogen. Because of this fact, and the need to maintain overall program variable storage requirements at a level that will fit into core, it was decided not to expand the program variable arrays to accommodate a third cryogen fluid, but instead, to use those portions of the arrays normally used for the hydrogen fluid to store the nitrogen fluid parameter values. Consequently, the Life Support subprogram became a fairly large self-contained subprogram, designated as subroutine ECLSS. Hence, subroutine CRYCØN makes only one call for the subprogram. In the case of a Life Support System analysis, the

values assigned, via input, to the variables SYSNUM, SCRIT and KSUBC (SYSNUM, I) would be,

SYSNUM = 3

SCRIT = 2

and KSUBC (3,I).

The preprogrammed data statement stored in core for this system analysis is, (KSUBC(3,I), I = 1,9)/7, 0, 0, 0, 0, 0, 0, 0, 0/. And the order of subprogram execution by subroutine CRYCON is as shown in the following table:

Table 1.1.3-5

CRYCON EXECUTION SEQUENCE FOR A LIFE
SUPPORT SYSTEM ANALYSIS

LOOP PASS	JKM VALUE	GO TO STATEMENT	SUB-PROGRAM CALLED
1	7	550	ECLSS
2	0	2200	Terminates Loop

As stated previously CRYCON calls subroutine OTPWSM, outputs the weight summaries and returns to CONTRL for a new case, or termination of the program.

1.1.3.2.5 Fuel Cell System Calculation Sequence. The cryogen fuel cell system as defined by this study is a fuel cell array fed by a supercritical fluids storage and supply subsystem. Further, the energy required for conditioning the reactant fluids and maintaining their super-critical condition in storage is wholly derived from the reject heat of the fuel cells. The subprogram which characterizes the fuel cell system is subroutine FUELCL. This rather large sub-program performs the system sizing calculations based upon the mass and energy transfer requirements of the input performance and duty cycle constraints.

The individual fluid circuit components and line segments are sized and weighed by subroutine CMPCAL which additionally supplies pressure drop calculations for the main reactant circuits.

For a fuel cell analysis, subroutine CRYCØN has the values assigned, via input data, for SYSNUM, SCRIT and KSUBC (SYSNUM, I), as follows:

SYSNUM = 4

SCRIT = 2

and KSUBC (4,I)

The preprogrammed data statement stored in core for fuel cell system analysis is, (KSUBC(4,I), I = 1,9)/5, 4, 0, 0, 0, 0, 0, 0, 0/.

The order of sub-program execution is as given in the following table.

Table 1.1.3-6
CRYCØN EXECUTION SEQUENCE FOR A FUEL
CELL SYSTEM ANALYSIS

<u>Loop Pass</u>	<u>JKM Value</u>	<u>GØ TØ Statement</u>	<u>Subprogram Called</u>
1	5	450	FUELCL
2	4	400	CMPCAL
3	0	2200	Terminates Loop

When the internal loop is terminated CRYCON calls subroutine OTPWSM, outputs the weight summaries and returns to CONTRL for a new case, or termination of the program.

1.1.3.2.6 Orbit Maneuvering System Calculation Sequence The orbit maneuvering system (OMS) employed in this study was defined to be a subcritical cryogen fluids pump-fed system. The OMS and ACPS analysis procedures are quite similar program-wise, with the principal differences being engine size, component size and the fact that the OMS has fewer, though larger components.

For an OMS analysis, SYSNUM, SCRIT and KSUBC (SYSNUM, I) will have the following values:

SYSNUM = 5

SCRIT = 1

and KSUBC (5,I).

The preprogrammed data statement stored in core for OMS analysis is:

(KSUBC(5,I), I = 1, 9)/6, 4, 10, 9, 8, 1, 10, 11, 2/

The order of sub-program execution by sub-routine CRYCON is identical to the order given in Table 1.1.3-2, and the subsequent remarks following that table.

1.2 INPUT DATA

The input data deck structure will vary according to the system to be analyzed and the type of fluid storage system employed. All input data cards are read within the body of subroutine CONTRL. The segments of input data to be read are generally divided into two groups; (1) input data common to all system analyses and (2) input data specific to a given system analysis. Necessarily a variety of read statement formats must be used and these are defined in labeled card formats given later in this discussion.

In general, a data input deck, for any system to be analyzed, will be made up of a set of card groups from the following group list:

- (a) User Identification Card (First Header Card)
- (b) Case Title Card (Second Header Card)
- (c) Table Data Echo Control Card
- (d) Add-File Card - To cause loading of "Table Data" file - or - Actual "Table Data" Deck may be placed here, replacing the Add-File card
- (e) System Definition Card
- (f) Configuration Definition Data Cards
- (g) Duty Cycle Definition Data Cards
- (h) Consumer Characterization Data Cards
- (i) Fluid Storage Tanks Characterization and Configuration Data Cards
- (j) Fluid Accumulator Characterization Data Card
- (k) Heat Exchanger Characterization Data Cards
- (l) Pump and Turbine Characterization Data Cards

- (m) Heat Source Characterization Data Cards
- (n) Motor Characterization Data Cards

Cards (a), (b), and (e) are read directly by subroutine CONTRL. Cards (c) and (d) are read by subroutine INTAB, called by CONTRL. Cards (f) through (n) are read by subroutine COMPIL, called by CONTRL.

1.2.1 Input Data - Card Definition and Description

Data definition and input card descriptions for data contained in the fourteen data card groups are presented in detail in the following subsections. Card data formats are presented in Subsection 1.2.

1.2 1.1 User I. D. and Case Title Cards.

Gp(a) Card-1

The User I. D. card identifies the analyst making the program run. This card is required in every run deck. The card contains the following information:

Name, Dept., Bldg., Extension

Gp(b) - Card-1

A case title card is to be provided for every system data deck as a means of providing run identification for the system being evaluated. Seventy-two (72) spaces are provided for the title. Short titles are to be centered in the 72 spaces.

1.2.1.2 Table Data Input Cards.

Gp(c) - Card-1

This card is the Table Data Echo control card. The variables contained on the card are: IFT, OFT, NPRT, NPRT2

IFT = Table Data Input Drum Unit
 OFT = Table Data Output Drum Unit
 NPRT = Table Data Echo Print Control
 = 0, Print All Tables, One Table per Page
 = 1, Print No Table Output
 = 2, Print All Tables with no page eject - Table Dump

NPRT2 = Control for Table Summary
 NPRT = 1 > Print Brief Table Summary
 NPRT2 = 1

Gp(d) - Card-1 (Normal Setup)

If the Table Data has been entered and stored as a DATA File, then the Data File may be assigned and Card-1 here will be a simple:

@ ADD,P FILNAM

where

FILNAM is the Data File nemonic.

If the Table Data is on cards to be read in at this time, then the Gp(d) cards will be the actual table data card sets as described in detail in Subsection 1.2.6.

Alternate Table Deck Input: (N-sets)

Gp(d) Card-1

The Table I. D. and Control Card will contain the following information:

Title	-	Table Title (Description)
ND	-	Number of Dimensions in Table (MAX = 7, MIN = 2)
NC	-	Number of Comment Cards in Table
IP	-	Plot Option (0 = No Plot, 1 = Plot Table)
NT	-	Table Number

GP(d) Card-2

Table Comment Card - Gives further description of table data and data reference sources. There may be NC comment cards.

Gp(d) Card-3

Table Subset Variable Card - Specifies additional variable and its values for Table Data Subsets.

LABV - Variable Label

NP - Number of Values to be used (is also number of data subsets)

TAB - Value, Value_z, ... Value_{np}

There must be (ND-2) of these cards present in Table Set. (ND = Number of dimensions in Table)

Gp(d) Card-4

Table Plot Control Card - Contains X-axis label, Y-axis label, X-MIN value, X-MAX value. One card is required for each Table Set.

Gp(d) Card-5

Table Data Subset Characterization Card - card contains:

NV - Number of Data Point Sets (X, Y) or Number of coefficients

TYPE - Type of Data in Table

= 0, Coefficients of polynomial

= 1, Discrete data points from curve

= 2, Equation

NIP - Number of points to be used for data interpolation

≤ NV

> 1

= 2, Linear Interpolation

= 3, parabolic or hyperbolic interpolation

There must be one of these cards for each data sub-set in the Table Set.

Gp(d) Card-6

Table Data Card - :

For discrete data there are three data sets (X, Y) per card arranged in order of increasing values of X, for NV sets of points.

For coefficients; coefficients are arranged in order of power and NV coefficients are read. (For example: $C_1X^2 + C_2X + C_3 = 0$; Input as C_1 , C_2 , C_3 and NV = 3)

There are NV/3 discrete data cards required, or NV/6 coefficient data cards required.

There will be N sets of the Gp(d) table card sets, where N equals the number of Table Data sets required for the program.

1.2.1.3 System Definition Card

Gp(e) Card-1

The system definition card provides the system identification; specifies whether the system has a subcritical or super-critical fluid supply subsystem; specifies whether or not additional systems are to be read in for additional case consideration; and, specifies which subprogram diagnostic switches are to be activated. The variables which are read are:

NSYS - First three letters of system name
 N1 - Additional six alpha spaces for rest of system name
 NCRIT - First three letters of subcritical or super-critical
 MDTRC - Diagnostic switch for eleven subprograms
 0, or , blank for NO Diagnostics
 1, turns ON Diagnostic switch as defined in PDP-CCNTRL

There must be one system definition card in each system input deck.

1.2.1.4 System Configuration Definition Data Cards

Gp(f) Card-1

The system configuration definition data represents the program image of the system schematic diagram. Only one (1) card format is employed which functions as a data input card, and as a configuration table END card. The flexibility of the data format card in providing different kinds of information resides in the technique of reading the array and changing the variable name to correspond to the value entered at any point in the array. Since each data card represents a specific item, such as, fluid, component, or line segment, and their associated

parameters, the data array is conveniently manageable.

The variables which are allocated to the card are as follows:

- CFUNCT - Six alpha characters which specify either the fluid, consumer assembly, or system component item, currently being considered. The allowable names are defined in DATA (FNAME) located in subroutine STODTA, and further described in PDP-CCNFIG

- CFTYPE - A single, or, two digit number which characterizes the type or kind of fluid, consumer assembly, or system component item

- CNOPER - Single digit number - for number of consumer assemblies, or component items operating in parallel; or, in the case of a fluid, the digit specifies the fluid state (i.e., 1 = gas; 2 = liquid)

- CNSTBY - Single digit number - for the number of consumer assemblies or component items in parallel standby condition (not operating)

- CMTYPE - Single Digit Number which specifies the material type for the system component item. CMTYPE values are defined in PDP-CCNFIG .

- FRCOEF - Variable containing the friction coefficient applicable to the system component item being considered

- LOD - Length over Diameter Ratio, or, Length applicable to the system component item under consideration (Real Number)

- DIAM - Diameter (I.D. or Port) applicable to system component item being considered

- CITYPE - Integer defining Insulation Type employed for system component item being considered

- ITHICK — Insulation thickness (Real Number) for system component item under consideration
- NBAR — Number (Real) of insulation layers per inch of thickness for component item being considered
- CODE — Six alpha character code name for component item under consideration. (i.e., PS02, etc.)

There must be one card for; (a) each fluid and fluid state change, (b) each fluid system consumer, (c) each fluid system component item, and (d) each fluid system line segment item. The cards are arranged starting with the oxidizer fluid system side and working from the consumer toward the fluid supply source. This is followed by the same arrangement for the fuel fluid side of the system. A typical configuration table is illustrated in the Input Data Deck Example given in Subsection 2.5. The very last card in the configuration data set must have END entered in the CFUNCT field, since this is required in subroutine COMPIL to terminate the READ loop. (It is also advisable to use card columns 73-80 to number the configuration data cards.)

1.2.1.5 System Duty Cycle Definition Data Cards

Gp(g) Card-1

The system duty cycle definition data cards contain the cyclic operating interval data required for each analysis. The variables employed are as given below. Note that the variable DCYCLE is in an array in which are stored alternate values of operating and non-operating time intervals:

DCYCLE(I) — Operating Time Interval

DCYCLE(I+1) — Non-operating Time Interval

PSI — Minimum Impulse Bit Degradation

NEOP — Number of Consumers Operating (Engines, Fuel Cells, etc.)

- HP - Horsepower -Average Value In Interval
- PAMB - Ambient Pressure-Average Value In Interval
- PKW - Power (KW)-Average Value In Interval
- RPRTIM - Time required per repressurization (cabin or airlock) during a given
 duty cycle Interval

There must be one card for each of the defined duty cycle interval periods in total mission span considered.

There must be a duty cycle end-card consisting of a negative number (i. e. , -1) in the DCYCLE (I+1) field

1.2.1.6 Consumer Characterization Data Cards. The consumer characterization data cards are specific to the system undergoing analysis and contribute the only significant change in the input data decks for the respective systems. Aside from the differing input data for the five kinds of consumer systems further differences occur when a given system has a sub-critical fluid supply subsystem, or when it has a super-critical fluid supply subsystem. Thus, there are seven separate consumer characterization data card sets which cover the range of program analysis capability.

1.2.1.6 1 Engine Consumer Data Cards: (ACPS or OMS).

Gp(h-1) Card-1

The engine consumer data card is utilized for both ACPS and OMS engine data since the required parameters are identical and the same variable names are used. The variables employed are defined as follows:

- NENG - Integer number of engines operating
- GITEMP - Fluid Inlet Temperature to Engine(s)
- GIPRES - Fluid Inlet Pressure to Engine(s)
- THRUST - Developed Thrust per Engine

- PSUBC - Engine Combustion Chamber Pressure
- EXPRAT - Engine Nozzle Expansion Ratio
- MIXRAT - Engine Oxidizer to Fuel Mixture Ratio (Real Number)

The single card is usually marked by placing the term ENG in card columns 78-80.

1.2.1.6.2 APU Consumer Data Cards. The APU Consumer input data requires two cards for either a subcritical or super-critical fluid fed system. The first card used in both cases is identical, while the second cards contain different information. The input cards required are as follows:

Gp(h-2) Card-1 (APU-Basic)

The following variables are input on the APU-Basic card:

- NAPU - Integer number of APUs operating
- HPR - Horsepower Rating of a single APU (Assumes all are identical)
- FMR - Oxidizer to Fuel Mixture Ratio of Gas Generator Driving APU Turbine
- PGG - Exit Pressure of Gas Generator driving APU Turbine
- TIT - Turbine Inlet Temperature (Assumed also to be exhaust temperature of gas generator driving APU turbine)
- TD - Exhaust discharge temperature from fluid conditioning heat exchangers

Gp(h-2) Card-2 (APU-Subcritical)

The variables input on the APU-Subcritical card are as follows:

- MRGGCH - Oxidizer to fuel mixture ratio for the gas generator driving the fuel fluid conditioning heat exchanger

MRGGCØ	– Oxidizer to fuel mixture ratio for the gas generator driving the oxidizer fluid conditioning heat exchanger
TDGGH	– Discharge temperature of gas generator for fuel conditioning heat exchanger
TDGGØ	– Discharge temperature of gas generator for oxidizer conditioning heat exchanger
TVH	– Temperature of residual vapor in fuel storage tank
TVØ	– Temperature of residual vapor in oxidizer storage tank
TENV	– Environment temperature around APU System

Gp(h-2) Card-3 (APU-Supercritical)

The variables entered in the APU Supercritical data card are as follows:

FMRG	– Oxidizer to fuel mixture ratio for supplementary gas generator
PFH	– Final fuel tank pressure
PFØ	– Final oxidizer tank pressure
TFH	– Final fuel tank temperature
TFØ	– Final oxidizer tank temperature
TG	– Exit gas temperature from supplemental gas generator
DELPCP	– Pressure rise (Delta-P) in tank circulating pump
TENV	– Environmental temperature around APU system

1.2.1.6.3 Life Support Consumer Data Cards. The Life Support Consumer Data Input variables require four input cards in two different card formats. The variables by card format are as follows:

Gp(h-3) Card-1

(O₂ = Oxygen, N₂ = Nitrogen)

MDAYS – Integer number of days in mission

NCREW – Integer number of crewmen on board spacecraft

NRPRES - Integer number of cabin or airlock prepressurization planned for mission

NDARES – Integer number of days of reserve fluids required

Ø2FNØM - Metabolic oxygen requirement (lbs. per man-day)

GLKRAT - Spacecraft atmosphere leakage rate (lbs. per day)

TLSNØM - Nominal temperature of gases supplied for life support (1) = ϕ_2 ;
 (2) = N₂

RHØBEG - Loading density at stored life support fluids (1) = Ø_g; (2) = N2

TKFTEM - Final fluid tank temperatures
 (1) = ϕ_2 ; (2) = N2

TKFPRS – Final fluid tank pressures
 (1) = \emptyset_2 ; (2) = N2

TENVR – Environment temperature around life support fluid storage tanks

CABVOL - Cabin (or airlock) volume

Gp(h-3) Card-2

- LINDIA - Fluid line diameter entering fluid conditioning heat exchanger
 (1) = Ø2; (2) = N2
- HTRFLX - Heater rating (BTU/HR-sq. in. ret. temp.)
 (1) For heaters in conditioning heat exchanger
 (2) For fluid tank heaters
- PLSNØM - Nominal pressure of delivered gaseous life support fluids
 (1) = Ø2; (2) = N2
- HTRDIA - Fluid tank heater diameter
 (1) = Ø2; (2) = N2
- HTRLNG - Fluid tank heater length
 (1) = Ø2; (2) = N2
- PSET1 - Lower pressure limit setting for Ø2 storage tank
- PSET2 - Lower pressure limit setting for N2 storage tank

1.2.1.6.4 Fuel Cell Consumer Data Cards. The fuel cell consumer data input variables require four data cards in three different card formats. The variables arranged by card format are as follows:

Gp(h-4) Card-1

- MRFC - Oxygen to hydrogen reactant mixture ratio for fuel cell
- SRCFC - Specific reactant consumption (lbs/KWH @ rated power output)
- QDTFC - Fuel cell heat rejection rate (BTU/KWH @ rated power output)

SPWTFC	- Fuel cell specific weight (LB/KW @ rated power output)
TFCNOM	- Nominal fuel cell gas fired temperature (1) = O_2 ; (2) = H_2
TF21IN	- F21 coolant fuel cell exit temperature
TF21 O_2	- F21 coolant fuel cell inlet temperature
TF O_2 FC	- Final O_2 reactant tank temperature
TFHFC	- Final H_2 reactant tank temperature
PF O_2 FC	- Final O_2 reactant tank temperature
PFHFC	- Final H_2 reactant tank temperature
RH O_2 FIL	- Reactant tank fill densities (1) = O_2 ; (2) = H_2
W O_2 VENT	- Estimated O_2 vent quantity
WHVENT	- Estimated H_2 vent quantity
DELTCP	- Pressure rise in reactant tank circulating compressor
TENV	- Environment temperature around fuel cell system
PRFC O_2 P	- Fuel cell operating pressure
P O_2 WN O_2 M	- Nominal fuel cell operating power level

Gp(h-4) Card-2

NFC O_2 P	- Integer number of fuel cells operating
--------------------	--

- NFCSTB - Integer number of fuel cells on standby
- PLSET1 - Lower limit pressure setting for Ø2 reactant tank
- PLSET2 - Lower limit pressure setting for H2 reactant tank
- VJANUL - Vacuum jacket annulus spacing (inches)
(1) = Ø2; (2) = H2
- TKMXDI - Maximum tank pressure vessel diameter permitted
(design constraint - inches)
(1) = Ø2; (2) = H2

Gp(h-4) Card-3

- FCVØLT - Nominal fuel cell voltage
- PRGRAT - Nominal fuel cell purge rate
(1) = Ø2; (2) = H2
- PRGTIM - Nominal fuel cell purge time (duration each purge)
(1) = Ø2; (2) = H2
- PRGINT - Purge interval in ampere hours
(1) = Ø2; (2) = H2

1.2.1.7 Fluid Tank Data Input Cards. The fluid tankage characterization data cards are common to systems encompassed in the major program. Variations which may occur in some systems are accommodated by simply entering zero values for the variables not used by the particular system considered. Tank geometry considerations are provided for in the program, with subprogram capability for calculating; spherical, cylindrical, cylindrical with hemispherical ends, cylindrical with conical ends, and combination tankage with a common bulkhead, hemispherical bottom and conical top with a hemispherical cap (such as the cryogen shuttle orbiter drop-tank). For special tank shapes having predetermined dimensions, the program will read in the dimensions and do the necessary calculations for

volume and surface area. For simple spherical tanks, or, simple cylindrical tanks with hemispherical ends, the program skips the special geometry input cards, and they must not be present in the input deck. The conditions controlling this branching option are specified in the tank geometry characterization sub-paragraph.

1.2.1.7.1 Fluid Tank Characterization DATA CARDS. The variables which characterize the fluid tank conditions and constraints are as follows:

Gp(i-1) Cards 1-4

NØP	- Number of tanks operating on line (same fluid)
SATYPE	- Fluid acquisition device type
SITYPE	- Tankage insulation type
SMTYPE	- Tank construction material type
SPTYPE	- Tank pressurization system type
SITEMP	- Tank initial fluid temperature
SIPRES	- Tank initial pressure
SPGTEM	- Pressurant gas temperature (inlet condition)
SØPRES	- Tank operating pressure
SVPRES	- Tank vent pressure setting
SHFLUX	- Heat leak flux into tank (BTU/HR-Sq. Ft.) (Optional)
SITHIK	- Tank insulation thickness (inches)
FLDLØD	- Wgt. of fluid loaded into tank (optional)
SULGPC	- Percent ullage (initial value for tank)

SMDIAM	– Maximum tank diameter (ft.)
SHØTEM	– Tank conditioning heat exchanger cold fluid outlet temperature
SHDELP	– Tank conditioning heat exchanger cold fluid pressure drop (psi)
SPDELP	– Tank circulating pump pressure rise (psi)
SGØTEM	– Tank conditioning heat exchanger gas generator outlet temperature
SGGPC	– Tank conditioning heat exchanger gas generator chamber pressure (outlet pressure)
SGMRAT	– Tank conditioning heat exchanger gas generator mixture ratio (ϕ / F).
SNBAR	– Number of layers per inch of tank insulation material. (multilayer insulation only)

Two sets of the above cards are read; the first set contains the data for the oxidizer tankage, and the second set contains the data for the fuel tankage. Two sets (8-cards) must be present in the data deck, even if one set is blank.

1.2.1.7.2 Fluid Tank Geometry Data Cards.

Gp(i-2) Card-5

Tank Option Card – Provides branching option to tank geometry subprograms when required for special tank shapes.

IWØP – Integer number specifying tank geometry option

NØSHAP – Integer number specifying number of tank shape cards to follow

Option Definitions

- If IWOP = 1 Subprogram will compute tank volume for a spherical tank.
If diameter of spherical tank exceeds value of SMDIAM, subprogram will add a cylindrical section between hemispheres with diameter equal to SMDIAM to accommodate tank volume required. Subprogram prints out requirement for cylindrical tank giving length of cylinder and diameter.
- If IWOP = 2 Subprograms will compute all parameters for a "Specific General Tank Configuration" - to be specified on input cards following this card.
- If IWOP = 3 Subprograms will compute all parameters for a "Fitted General Tank Configuration" in which all tank segments are specified except the length of the major cylindrical section. This "Length" will be computed by the subprograms to "fit" the required tank volume generated by system fluid consumption computations.

If, $IWOP < 2$, and $NOSHAP = 0$, the $IWOP = 1$ Option is executed automatically, and there are no tank shape cards following the option card. If, $IWOP \geq 2$, then $NOSHAP$ must specify the number of tank shapes involved and that many "shape cards" will have to be present following the Tank Option Card.

Gp(i-3) Card-6

Tank shape card(s) - the tank shape cards specify the geometric shape(s) involved in the tank structure in their order of consideration, the fluid contained by the tank, and the dimensions associated with each shape segment. The variables input in this card are as follows:

- JTKTYP - Integer value which specifies tank segment shape (see notes)
- JFLTYP - Integer value which specifies fluid contained in tank segment shape

XD - Shape "X" dimension (see notes)

YD - Shape "Y" dimension (see notes)

ZD - Shape "Z" dimension (see notes)

Notes: Variable Specifications

JTKTYP = 1, for cylinder
 = 2, frustrum of cone
 = 3, hemi-ellipsoid
 = 4, cylinder plus hemi-ellipsoid
 = -2, inverted frustrum of cone
 = -3, inverted hemi-ellipsoid (bulkhead)

JFLTYP = 1, oxidizer fluid
 = 2, fuel fluid
 = -1 oxidizer at common bulkhead
 = -2, fuel at common bulkhead

For JTKTYP = 1,

XD = Height (ft)

YD = Radius (ft)

For JTKTYP = 2, or, -2,

XD = height (ft.)

YD = radius of top (ft.)

ZD = radius of bottom (ft.)

For JTKTYP = 3, or, -3

XD = radius along axis of rotation (ft.)

YD = radius perpendicular to axis of rotation (ft.)

For JTKTYP = 4,

XD = radius (and cylinder height) along axis of rotation (ft.)

YD = radius perpendicular to axis of rotation (ft.)

One card is necessary for each tank segment shape and the order of input is from the tank "Bottom" to the tank "Top".

1.2.1.8 Accumulator Data Input Cards. For those systems requiring an accumulator tank for the storage of gaseous fluid, provision is made for inputting the required accumulator data. The branching function permitting the reading of data specified in this and the following subsections is controlled by preprogrammed data statements called "INBLK", defined as DATA ((INBLK(SYSNUM, I, J), I = 1,5), J = 1,2). The five data statements, one for each major system, define which of five sets of major component input data cards are to be read for any given system. The five INBLK data statements will be found in subroutine STØDTA, INBLK is defined in PDP-CCNTRL. If INBLK(SYSNUM, 1,J) is set equal to one (1), the system requires and will read in accumulator data; conversely, if INBLK(SYSNUM, 1,J) equals zero, no accumulator is required and the accumulator input cards will not be present in the input data deck.

The variables which are input in the accumulator data input cards are as follows: six cards (two sets) are required since the variables for each fluid accumulator are entered separately. The variables for the oxidizer accumulator are entered first, followed by the variables for the fuel fluid accumulator.

Gp(j) Cards 1-3

NAØP	— Integer value for number of accumulators operating for one fluid
AITYPE	— Accumulator insulation type
AMTYPE	— Accumulator structural material type
ATEMP	— Operating temperature for accumulator
APRES	— Operating pressure for accumulator
AHFLUX	— Heat leak rate into accumulator (Btu/hr-ft ²)
AITHIK	— accumulator insulation thickness (inches)

AVØL	- Accumulator volume (cu. ft.)
ADIAM	- Accumulator maximum diameter (ft.)
ANDELP	- Pressure drop swing allowed in accumulator (psi)
ANBAR	- Number of insulation layers per inch of thickness (multilayer insulation only)

Note that if INBLK (SYSNUM, 1,J) is zero, then there will be no accumulator data cards in the input data deck.

1.2.1.9 Heat Exchanger Data Input Cards. A requirement for heat exchangers of one form or another usually exists in most of the cryogen systems one can envision, except for the liquid fed OMS system. And, (as described in subsection 1.2.1.8) if INBLK (SYSNUM, 2,J) = 1, then heat exchangers are required and input data cards must be present, otherwise they are deleted.

Heat exchangers in a two fluid system usually occur in pairs, except for the case where a single supplementary heat exchanger might be required to make up for a potential energy deficiency resulting from a limited heat source capability. For purposes of uniformity, heat exchanger data will always be input for pairs of exchangers even if one of the pair does not exist. In this case, the non-existent exchanger is represented by a dummy (or blank) data card.

The heat exchanger variables required for input employ only two card formats. The second card is repeated for each exchanger in sets of two. The first card contains data for the first oxidizer heat exchanger occurring upstream of the system consumer, and the second card contains data for its fuel side equivalent. Additional data sets are input for other heat exchangers encountered as the schematic layout progresses toward the fluid supply tanks. The variables which are input on the Heat Exchanger Data Input Cards are doubly subscripted and are stored in a double array.

For example, "HXCODE (4,1) = HX07" is the heat exchanger schematic code symbol for the oxidizer (4, 1) heat exchanger of the fourth (4, 1) set of heat exchangers occurring up-

stream of the cryogen consumer.

The variables employed as input are as follows:

Gp(k) Card-1

NUMHEX - Integer value for number of pairs of heat exchangers being considered

One card is required if heat exchanger data is to be input.

Gp(k) Card-2

HEXHIT - Hot fluid inlet temperature ($^{\circ}\text{R}$)

HEXHØT - Hot fluid outlet temperature ($^{\circ}\text{R}$)

HEXCIT - Cold fluid inlet temperature ($^{\circ}\text{R}$)

HEXCØT - Cold fluid outlet temperature ($^{\circ}\text{R}$)

HEXHIP - Hot fluid inlet pressure (psia)

HEXHØP - Hot fluid outlet pressure (psia)

HEXCIP - Cold fluid inlet pressure (psia)

HEXCØP - Cold fluid outlet pressure (psia)

HXHDLP - Hot fluid pressure drop (psi)

HXCDDL - Cold fluid pressure drop (psi)

HXMRAT - Heat exchanger gas generator Ø/F mixture ratio

HXCØDE - Heat exchanger identification code symbol

Two cards are required for each pair of exchangers; oxidizer unit first followed by fuel side unit, when data is to be input.

1.2.1.10 Pump and Turbine Data Input Cards. The requirement for pump, or turbine data for any of the systems considered is preprogrammed in the stored INBLK data. If INBLK (SYSNUM, 3, J) = 1, then either pump or pump and turbine data are required to be input, otherwise the data cards are deleted. The pump data input cards contain three separate sets of information; (a) Pump data (high pressure); (b) Transfer pump data; and (c) Turbine data.

The six cards which make up the pump and turbine data card set consist of two pump data cards (one for each fluid), two transfer pump data cards (one for each fluid), and two turbine data cards (one for each fluid). All six cards must be present if any of the data are required. Non-pertinent variables are simply left blank.

The variables required as input are as follows:

Gp (1) Cards 1-2

PTYPE - Interger value for pump type
 PTYPE = 1, for pump only
 PTYPE = 2, for turbopump assy

PEFF - Pump efficiency

PNPSH - Pump net positive suction head (psi)

PSSPED - Pump speed (rpm)

EPDELP - Estimated pump pressure rise (psi)

Gp (1) Cards 3-4

TPEFF - Transfer pump efficiency

TPNPSH - Transfer pump net positive suction head (psi)

TPDELP - Transfer pump pressure rise (psi)

TPWDØT - Transfer pump flow rate (lb/sec)

Gp (l) Cards 5-6

TEFF - Turbine efficiency

TITEMP - Turbine inlet temperature ($^{\circ}$ R)

TØTEMP - Turbine outlet temperature ($^{\circ}$ R)

TMRATØ - Turbine gas generator Ø/F mixture ratio

TGGPC - Exhaust pressure of turbine gas generator (psia)

Note: For high and medium pressure pumps subroutine PARPMP will calculate pump speed and net positive suction pressure required. Thus input values need only be nominal.

1.2.1.11 Heat Source Data Input Cards. The requirement for heat sources, usually in the form of gas generators, for any given cryogen system is usually associated with a requirement for heat exchangers and turbines where waste heat is not available, or, insufficient for the energy needed. For the defined cryogen systems, accommodated by the Math Model Program, the heat source requirements are imbedded in the stored INBLK data. Thus, if the value of INBLK (SYSNUM, 4, J) = 1, the heat source data are required, otherwise the data cards are deleted from the input deck.

Heat sources in a two fluid system usually occur in pairs, except for the case where a single supplementary heat source might be required to make up for an energy deficiency.

For purposes of uniformity in data handling, heat source data is always arranged such that data for a heat source in the oxidizer side of the system is input first, followed by the same data for the equivalent heat source in the fuel side of the system (i.e., paired sources). If one of the sources does not exist, then a dummy (or blank) card is entered

in its place. The first pair of input data cards will contain data for the first pair of heat sources closest to the cryogen consumer. Additional data sets are then input for each pair of heat sources encountered while going through the system schematic toward the fluid supply tanks. As with the heat exchanger data, the variables are doubly subscripted and match the heat sources to the heat exchanger by position and fluid index.

The variables employed in heat source data input are as follows:

Gp (m) Card-1

NUMHSØ - Integer value for number of pairs of heat sources being considered

One card is required if heat source data is to be input.

GP (m) Card-2

HSTYPE - Integer value for heat source type
 HSTYPE = 1, for gas generator only
 HSTYPE = 2, for waste heat input only
 HSTYPE = 3, for gas generator and waste heat combination

HSMRAT - Heat source Ø/F mixture ratio

HSØTEM - Heat source outlet temperature (°R)

HSAEE - Heat source available energy (BTUs)

HSPRES - Heat source outlet pressure (psia)

Two cards are required for each pair of heat source units; oxidizer side unit first followed by fuel side unit – when data is to be input.

1.2.1.12 Electric Motor Data Input Cards. The requirement for motor driven pumps, transfer pumps, or compressors exists in some of the smaller cryogen systems where pumping horsepower needed is small, or the duty cycle is light. For the cryogen systems

considered in this program, the requirement for using electric motor data has been embedded in the preprogrammed-stored INBLK data. If, for any specified system, the value of INBLK (SYSNUM, 5, J) = 1, the electric motor data are required; if otherwise, the data cards do not appear in the input data deck.

The variable employed for input at the electric motor data are as follows:

Gp (n) Card-1

- MTYPE - Integer value for motor type

- MEFF - Motor efficiency

- MSS - Motor speed (rpm)

- PDNSTY - Power density of battery driving electric motors

One card is used if motor data is required. If not required the card is deleted from the input deck.

1.2.2 Input Data Card and Card Format Description

The input data cards which make up the program input data deck are defined by the Read Statements located in Subroutines CØNTRØL, INTAB, and CØMPIL. This subsection presents a graphic description of each input card as an aid in visualizing and arranging the individual system input data decks needed for the analytical operation of the program. Included as aids, are several tables which explain and define the construction and insulation material types employed by the various subprograms. Included also as aids in program data setup are several tables which define and explain important variables that occur repeatedly. Table 1.2.2-1 presents the variable names employed for control, branching and switching purposes. Table 1.2.2-2 presents the configuration variable names and definition. Following the tables are the data sheets which present the input data card formats.

Table 1.2.2-1

VARIABLE NAMES EMPLOYED FOR CONTROL, BRANCHING, AND SWITCHING PURPOSES

1. System Identification: (Subroutine CØNTRL)

<u>Variable Read</u>	<u>Alpha Input</u>	<u>Variable Equivalent</u>	<u>Integer Value</u>	<u>System Defined</u>
NSYS	ACP	NAMSYS	1	Attitude Control Propulsion System (ACPS)
NSYS	APU	NAMSYS	2	Auxiliary Power Unit (APU)
NSYS	EC/	NAMSYS	3	Life Support System (EC/LSS)
NSYS	FUE	NAMSYS	4	Fuel Cell System (Fuel Cell)
NSYS	ØMS	NAMSYS	5	Orbit Maneuvering System (ØMS)

2. Control Variables: (Subroutine CØNTRL)

<u>Control Variable</u>		<u>Integer Value</u>	<u>Description</u>
SYSNUM	=	1	Controls Selection of Subprograms for ACPS
	=	2	Controls Selection of Subprograms for APU

Table 1.2.2-1 (Cont'd)

2. Control Variables (Subroutine CØNTRL) (Cont'd)

<u>Control Variable</u>		<u>Integer Value</u>	<u>Description</u>
SYSNUM	=	3	Controls Selection of Subprograms for ECLSS
(Cont'd)	=	4	Controls Selection of Subprograms for Fuel Cell
	=	5	Controls Selection of Subprograms for OMS
SCRIT	=	1	Specifies Subcritical Fluid Supply
	=	2	Specifies Supercritical Fluid Supply

3. Branching and Switching Variables:

MDTRC - Diagnostic Trace Switch, Read in by Subroutine CØNTRL, Used by CRYCØN.
Defined in PDP-CCNTRL.

MDTRC ()	=	Diagnostic Trace Switch for CRYCØN (OFF = 0)
(1)	=	1 Turn on ACCRES
(2)	=	1 Turn on ACQWT
(3)	=	1 Turn on APUSUB or APUSUP
(4)	=	1 Turn on CMPCAL
(5)	=	1 Turn on FUELCL
(6)	=	1 Turn on CØNSUM
(7)	=	1 Turn on ECLSS
(8)	=	1 Turn on LIQRES
(9)	=	1 Turn on TANK
(10)	=	1 Turn on TSIZEI
(11)	=	1 Turn on WTACC

MDTRC(1) is Card Column 70, ---MDTRC(11) is Card Column 80 of the System Specification Card

INBLK - Controls input data selection in subroutine CØMPIL via preprogrammed set of switches.

System Specification

INBLK (SYSNUM, I, SGRIT)

Input Selection Index

Fluid Subsystem Type

Table 1.2.2-1 (Cont'd)

DATA STATEMENT DEFINITION:

DATA ((INBLK(1,I,J),I = 1,5),J = 1,2)/1,1,1,1,0,	1,1,0,1,0/
DATA ((INBLK(2,I,J),I = 1,5),J = 1,2)/1,1,1,1,1,	1,1,0,1,0/
DATA ((INBLK(3,I,J),I = 1,5),J = 1,2)/0,0,0,0,0,	0,1,0,0,0/
DATA ((INBLK(4,I,J),I = 1,5),J = 1,2)/0,1,0,1,0,	0,1,1,0,1/
DATA ((INBLK(5,I,J),I = 1,5),J = 1,2)/0,0,0,0,0,	0,0,1,0,0/

For:

- I = 1, Read Accumulator Data - If INBLK = 1
- = 2, Read Heat Exchanger Data - If INBLK = 1
- = 3, Read Pump Data - If INBLK = 1
- = 4, Read Heat Source Data - If INBLK = 1
- = 5, Read Motor Data - If INBLK = 1

KSUBC - Preprogrammed Branching Variable for specified system analysis program selection - Used in subroutine CRYCØN. Defined in STØDTA.

System Specification

Subprogram Index

KSUBC (SYSNUM, I)

DATA STATEMENT DEFINITION:

DATA (KSUBC(1,I), I = 1, NBRSR) /6,4,10,9,8,1,10,11,2/
DATA (KSUBC(2,I), I = 1, NBRSR) /6,3,4,10,11,2,0,0,0/
DATA (KSUBC(3,I), I = 1, NBRSR) /7,0,0,0,0,0,0,0,0/
DATA (KSUBC(4,I), I = 1, NBRSR) /5,4,0,0,0,0,0,0,0/
DATA (KSUBC(5,I), I = 1, NBRSR) /6,4,10,9,8,1,10,11,2/

JAPUS - Switching variable which reverses order of subprogram selection for APU subcritical or supercritical analysis. Used in subroutine CRYCØN, values defined in subroutine STØDTA.

Fluid Subsystem Type

Subprogram Reordering Index

JAPUS (SCRIT, I)

DATA STATEMENT DEFINITION:

DATA JAPUS(1,1), JAPUS (1,2) /4,3/
DATA JAPUS(2,1), JAPUS (2,2) /3,4/

Table 1.2.2-2

CONFIGURATION VARIABLE NAMES AND DEFINITIONS

(Used by Subroutine CØMPIL, CMPCAL and LSSCMP)

1. Defined Configuration Names:

<u>Defined Variable</u>	<u>Input Alpha</u>	<u>Variable Equivalent</u>	<u>Integer Value</u>	<u>Component Item</u>
CFUNCT	GAS	FNAME	1	FLUID
CFUNCT	ENGINE	FNAME	2	ENGINE
CFUNCT	LINE	FNAME	3	LINE
CFUNCT	CØNTRL	FNAME	4	CØNTRØL
CFUNCT	FITTING	FNAME	5	FITTING
CFUNCT	TAP	FNAME	6	FLUID TAP
CFUNCT	TEE	FNAME	7	TEE
CFUNCT	ELBOW	FNAME	8	ELBOW
CFUNCT	VALVE	FNAME	9	VALVE
CFUNCT	REG	FNAME	10	REGULATOR
CFUNCT	ACCUM	FNAME	11	ACCUMULATOR
CFUNCT	TANK	FNAME	12	TANK
CFUNCT	PUMP	FNAME	13	PUMP
CFUNCT	HEX	FNAME	14	HEAT EXCHANGER
CFUNCT	TRBINE	FNAME	15	TURBINE
CFUNCT	F-CELL	FNAME	16	FUEL CELL
CFUNCT	EC/LSS	FNAME	17	LIFE SUPPORT
CFUNCT	END	FNAME	18	END OF TABLE

2. Configuration Variable Definitions:

CONFIGURATION FUNCTION CODE AND TYPE.

CFUNCT = 1, GAS	CFTYPE-1 = OXYGEN	2 = HYDROGEN
CFUNCT = 2, ENGINE	CFTYPE-1 = HI-PRESSURE	2 = LO-PRESSURE
CFUNCT = 3, LINE	CFTYPE = 10A FIXED NUMBER	

Table 1.2.2-2 (Cont'd)

CFUNCT = 4, CONTROL	<p>USES TWO DIGIT INDEX AS FOLLOWS,</p> <p>IDV = TENS DIGIT (10, 20, etc.)</p> <p>CFTYPE = UNITS DIGIT (1, 2, etc.)</p> <p>IDV = 10 FOR LIGHT WEIGHT CONTROL</p> <p>= 20 FOR MEDIUM WEIGHT CONTROL</p> <p>= 30 FOR HEAVY WEIGHT CONTROL</p> <p>= 40 FOR EXTRA HEAVY WEIGHT CONTROL</p> <p>CFTYPE = 1 FOR VALVE</p> <p>= 2 FOR REGULATOR</p> <p>= 3 FOR ORIFICE</p> <p>= 4 FOR FLOW METER</p>
CFUNCT = 5, FITTING	<p>USES TWO DIGIT INDEX AS FOLLOWS,</p> <p>LDV = TENS DIGIT (10, 20, etc.)</p> <p>CFTYPE = UNIT DIGIT (1, 2, etc.)</p> <p>LDV = 10 FOR USE IN LINE ONLY</p> <p>= 20 FOR 4-WAY TEE</p> <p>= 30 FOR 3-WAY TEE</p> <p>CFTYPE = 1 FOR TEE</p>
CFUNCT = 6, TAP	<p>USES TWO DIGIT INDEX AS FOLLOWS,</p> <p>LDV = TENS DIGIT (10, 20, etc.)</p> <p>CFTYPE = UNITS DIGIT (1, 2, etc.)</p> <p>LDV = 10 FOR USE IN LINE ONLY</p> <p>= 20 FOR 4-WAY TEE</p> <p>= 30 FOR 3-WAY TEE</p> <p>CFTYPE = 1 FOR TEE</p>
CFUNCT = 7, TEE	<p>USES TWO DIGIT INDEX AS FOLLOWS,</p> <p>LDV = TENS DIGIT (10, 20, etc.)</p> <p>CFTYPE = UNITS DIGIT (1, 2, etc.)</p> <p>LDV = 10 FOR USE IN LINE ONLY</p> <p>= 20 FOR 4-WAY TEE</p> <p>= 30 FOR 3-WAY TEE</p>

Table 1.2.2-2 (Cont'd)

CFUNCT = 8, ELBOW	<p>USES TWO DIGIT INDEX AS FOLLOWS,</p> <p>LDV = TENS DIGIT (10, 20, etc.)</p> <p>CFTYPE = UNITS DIGIT (1, 2, etc.)</p> <p>LDV = 10 FOR USE IN LINE ONLY</p> <p>= 20 FOR 90 DEG ELBOW</p> <p>= 30 FOR 45 DEG ELBOW</p> <p>CFTYPE = 1 FOR ELBOW</p>
CFUNCT = 9, VALVE	<p>USES TWO DIGIT INDEX AS FOLLOWS,</p> <p>IDV = TENS DIGIT (10, 20, etc.)</p> <p>CFTYPE = UNITS DIGIT (1, 2, etc.)</p> <p>IDV = 10 FOR LIGHT WEIGHT CONTROL</p> <p>= 20 FOR MEDIUM WEIGHT CONTROL</p> <p>= 30 FOR HEAVY WEIGHT CONTROL</p> <p>= 40 FOR EXTRA HEAVY WEIGHT CONTROL</p> <p>CFTYPE = 1 FOR VALVE</p>
CFUNCT = 10, REGULATOR	<p>USES TWO DIGIT INDEX AS FOLLOWS,</p> <p>IDV = TENS DIGIT (10, 20, etc.)</p> <p>CFTYPE = UNITS DIGIT (1, 2, etc.)</p> <p>IDV = 10 FOR LIGHT WEIGHT CONTROL</p> <p>= 20 FOR MEDIUM WEIGHT CONTROL</p> <p>= 30 FOR HEAVY WEIGHT CONTROL</p> <p>= 40 FOR EXTRA HEAVY WEIGHT CONTROL</p> <p>CFTYPE = 1 FOR REGULATOR</p>
CFUNCT = 11, ACCUM	NO OPTIONS
CFUNCT = 12, TANK	(SEE TANK ROUTINE)

Table 1.2.2-2 (Cont'd)

CFUNCT = 13, PUMP USES TWO DIGIT INDEX AS FOLLOWS,
 JOPTN = TENS DIGIT (10, 20, etc.)
 CFTYPE = UNITS DIGIT (1, 2, etc.)
 JOPTN = 10 FOR MINIMUM POWER PUMP
 = 20 FOR MINIMUM WEIGHT PUMP
 CFTYPE = 1 FOR HI-PRESSURE PUMP
 CFTYPE = 2 FOR LO-PRESSURE PUMP

CFUNCT = 14, HEX CFTYPE = 1 FOR HI-PRESSURE
 = 2 FOR LO-PRESSURE

CFUNCT = 15, TURBINE NO OPTIONS

CFUNCT = 16, FUEL CELL NO OPTIONS

CFUNCT = 17, ECLSS NO OPTIONS

CFUNCT = 18, END NO OPTIONS

CMTYPE - CONFIGURATION MATERIAL TYPE

CMTYPE = 1, 321/347 STAINLESS STEEL /
 = 2, 2219-T87 ALUMINUM ALLOY
 = 3, 6061-T6 ALUMINUM ALLOY
 = 4, INCONEL-718 ALLOY
 = 5, TITANIUM Ti-6Al-4V ALLOY
 = 6, CRES VACUUM JACKETED LINE
 = 7, 2219 VACUUM JACKETED LINE

CITYPE - CONFIGURATION INSULATION TYPE

CITYPE = 1, DOUBLE ALUMINUM MYLAR/SILK NET
 = 2, DOUBLE GOLD MYLAR/SILK NET
 = 3, DOUBLE ALUMINUM MYLAR/TISSUE GLASS

Table 1.2.2-2 (Cont'd)

CITYPE	= 4, CRINK DOUBLE ALUMINUM MYLAR
	= 5, NRC-2 CRINKLED ALUMINIZED MYLAR
	= 6, SUPERFLOC
	= 7, MICROSPHERES (104-135 MICRON)
	= 8, POLYURETHANE FOAM
	= 9, FIBERGLASS BATTING (JM)
CNOPER	- NUMBER OF OPERATIONAL UNITS (CFUNCT)
CNSTBY	- NUMBER OF STANDBY UNITS (CFUNCT)
CONFIG	- CONFIGURATION TABLE
COLUMN 1	CONTAINS THE ABOVE SIX (6) VARIABLES PACKED ONE PER BYTE IN THE ORDER THEY ARE LISTED FROM LEFT TO RIGHT IN THE WORD.
COLUMN 2	CONTAINS THE FLOW FRICTION COEFFICIENT
COLUMN 3	CONTAINS THE LENGTH OF A LINE OR THE EFFECTIVE L/D FOR OTHER COMPONENTS
COLUMN 4	CONTAINS THE DIAMETER OF A LINE
COLUMN 5	CONTAINS THE INSULATION THICKNESS FOR A LINE

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY, INC. Title USER ID CARD CASE TITLE CARD	Page	Temp.	Perm.
Checked by:	Date		Model		
Approved by:	Date		Report No. 1.2.2.1		

CARD TYPE - $G_p(a)$ CARD-1

CARD FUNCTION - User Identification Card

READ BY - Subroutine CØNTRL

CARD FORMAT (2AC, 2XA4, 3XA3, 1XA5)

NAME																																																												DEPT								BLDG								EXT														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80											

CARD TYPE - G_p(b) CARD-1

CARD FUNCTION - Case Title Card

READ BY - Subroutine CØNTRL

CARD FORMAT - (12AC)

Diagram illustrating the layout of a 128-bit data structure. The structure is divided into four sections, each labeled "CTITLE" with a double-headed arrow indicating its extent. The sections are defined by bit positions 1 through 128:

- Section 1: Bits 1 to 31 (labeled "CTITLE")
- Section 2: Bits 32 to 111 (labeled "CTITLE")
- Section 3: Bits 112 to 128 (labeled "CTITLE")
- Section 4: Bits 129 to 159 (labeled "CTITLE")

The bit positions are numbered 1 through 128 along the bottom of the diagram.

CARD TYPE	- $G_p(c)$ CARD-1
CARD FUNCTION	- TABLE DATA ECHO CONTROL CARD
READ BY	- SUBROUTINE INTAB
CARD FORMAT	- (5I5)

[illegible]

CARD TYPE	- G _P (d) CARD-1
CARD FUNCTION	- TABLE DATA FILE - ADD CARD
READ BY	- SUBROUTINE INTAB
CARD FORMAT	- QADD,P FILNAM
REF.	- UNIVAC-1108 MANUAL

@ADD, P FILNAM

IFT					ϕ_{FT}					NPRT					NPRT2					(BLANK)				
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

[illegible]

The diagram illustrates the layout of a card with the following fields:

- CARD TYPE
- CARD FUNCTION
- CARD FORMAT
- COMMENT (indicated by a long double-headed arrow spanning the majority of the card width)

[illegible]

CARD TYPE	- G _p (e) CARD-1
CARD FUNCTION	- SYSTEM DEFINITION CARD
READ BY	- SUBROUTINE CONTROL
CARD FORMAT	- (A3, A6, 3X, A3, 14X, A3, 37X, 11I1)

NSYS										NI										NCRIT										INTGR										MDTRC									
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50

GO TO NEXT PAGE

- NOT A CARD -

- NOT A CARD -

- G_p(f) CARD-1

- CONFIGURATION DATA CARD

- SUBROUTINE COMPIL

- (A6, I4, 3I5, 3F5.0, I5,
2F5.0, 5X, A6)

[illegible]

- $G_p(f)$ CARD-2

- CONFIGURATION DATA END CARD

- SUBROUTINE COMPIL

- (A6, I4, 3I5, 3F5.0, I5,
2F5.0, A6)

END						NOT USED																																																																															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80						

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY. INC.	Page	Temp.	Perm.
Checked by:	Date	Title DUTY CYCLE DEFINITION DATA CARD	Model		
Approved by:	Date		Report No. 1.2.2.6		

CARD TYPE - G_p(g) CARD-1

CARD FUNCTION - DUTY CYCLE DATA CARD

READ BY - SUBROUTINE CØMPIL

CARD FORMAT - FØRMAT (3F10.0, I5, 3F10.0, F7.0)

DCYCLE (I)	DCYCLE (I+1)	PSI	NEØP	HP	PAMP	PKW	RPRTIM	
0000000000	0000000000	0000000000	000000	0000000000	0000000000	0000000000	00000000	00000000
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35	36 37 38 39 40 41 42 43 44 45	46 47 48 49 50 51 52 53 54 55	56 57 58 59 60 61 62 63 64 65	66 67 68 69 70 71 72	73 74 75 76 77 78 79 80

CARD TYPE - G_p(g) CARD-1

CARD FUNCTION - DUTY CYCLE DATA END CARD

READ BY - SUBROUTINE CØMPIL

CARD FORMAT - (3F10.0, I5, 3F10.0, F7.0)

NOT USED	-1	NOT USED						
0000000000	0000000000	0000000000	000000	0000000000	0000000000	0000000000	00000000	00000000
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35	36 37 38 39 40 41 42 43 44 45	46 47 48 49 50 51 52 53 54 55	56 57 58 59 60 61 62 63 64 65	66 67 68 69 70 71 72	73 74 75 76 77 78 79 80

NENG	GITEMP					GIPRES					THRUST					PSUBC					EXPRAT					MIXRAT																																																					
	000000	0000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000																																																																
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

[illegible]

```

CARD TYPE          - Gp(h-2) CARD-1
CARD FUNCTION      - APU CONSUMER INPUT DATA CARD - APU BASIC
                   DATA
READ BY            - SUBROUTINE COMPIL
FORMAT             - (I5, 5X, 5F10.0)

```

[illegible]

CARD TYPE	- G _p (h-2) CARD-2
CARD FUNCTION	- APU CONSUMER INPUT DATA CARD-APU SUBCRITICAL DATA
FORMAT	- (7F10.0)

MRGGCH	MRGGCø	TDGGH	TDGGø	TVH	TVø	TENV	
0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68 69 70	71 72 73 74 75 76 77 78 79

CARD TYPE	- G _p (h-2) CARD-3
CARD FUNCTION	- APU CONSUMER INPUT DATA CARD - APU SUPERCRITICAL DATA
CARD FORMAT	- (7F10.0)

FMRG	PFH	PFØ	TFH	TFØ	TG	DELPCP	
0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
1 2 3 4 5 6 7 8 9 10 11	12 13 14 15 16 17 18 19 20 21	22 23 24 25 26 27 28 29 30 31	32 33 34 35 36 37 38 39 40 41	42 43 44 45 46 47 48 49 50 51	52 53 54 55 56 57 58 59 60 61	62 63 64 65 66 67 68 69 70 71	72 73 74 75 76 77 78 79 80

TENV										NOT USED																																																																					
0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000																																																		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY, INC.	Page	Temp.	Perm.
Checked by:	Date		Model		
Approved by:	Date				
Title			Report No.		
LIFE SUPPORT CONSUMER DATA CARDS			1.2.2.9		

CARD TYPE - G_p (h-3) CARD-1
 CARD FUNCTION - LIFE SUPPORT INPUT DATA CARDS
 READ BY - SUBROUTINE CØMPIL
 FORMAT - (4I5, 5F10.0/(7F10.0))

M DAYS	N CREW	NPPRES	NDARES	Ø2FNØM	GLKRAT	TLSNØM(1)	TLSNØM(2)	RHØBEG(1)	
000000	000000	000000	000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000
1 2 3 4 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68 69 70	71 72 73 74 75 76 77 78 79 80

RHØBEG(2)	TKFTEM(1)	TKFTEM(2)	TKFPRS(1)	TKFPRS(2)	TENVR	CABVØL	
0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68 69 70	71 72 73 74 75 76 77 78 79 80

CARD TYPE - G_p (h-3) CARD-2
 CARD FUNCTION - LIFE SUPPORT INPUT DATA
 CARD FORMAT - (7F10.0/5F10.0)

LINDIA(1)	LINDIA(2)	HTRFLX(1)	HTRFLX(2)	PLSNØM(1)	PLSNØM(2)	HTRDIA(1)	
0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000	0000000000
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68 69 70	71 72 73 74 75 76 77 78 79 80

HTRDIA(2)	HTRLNG(1)	HTRLNG(2)	PSETI	PSET2	
0000000000	0000000000	0000000000	0000000000	0000000000	0000000000
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

Prepared by:	Date	LOCKHEED MISSILES & SPACE COMPANY, INC.	Page	Temp.	Perm.
Checked by:	Date		Model		
Approved by:	Date				
		Title	Report No.		
		FUEL CELL CONSUMER DATA CARDS	1.2.2.10		

CARD TYPE - G_p(h-4) CARD-1
 CARD FUNCTION - FUEL CELL INPUT DATA CARDS
 READ BY - SUBROUTINE COMPIL
 CARD FORMAT - (10F7.0)

MRFC	SRCFC	QPTFC	SPWTFC	TFCNOM(1)	TFCNOM(2)	TF2LIN	TF21ØU	TFØFC	TFHFC	
00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
1 2 3 4 5 6 7	8 9 10 11 12 13 14	15 16 17 18 19 20 21	22 23 24 25 26 27 28	29 30 31 32 33 34 35	36 37 38 39 40 41 42	43 44 45 46 47 48 49	50 51 52 53 54 55 56	57 58 59 60 61 62 63	64 65 66 67 68 69 70	71 72 73 74 75 76 77 78 79 80

PFØFC	PFHFC	RHØFIL(1)	RHØFIL(2)	WØVENT	WHVENT	DELICP	TENV	PRFCØP	PØWNOØM	
00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
1 2 3 4 5 6 7	8 9 10 11 12 13 14	15 16 17 18 19 20 21	22 23 24 25 26 27 28	29 30 31 32 33 34 35	36 37 38 39 40 41 42	43 44 45 46 47 48 49	50 51 52 53 54 55 56	57 58 59 60 61 62 63	64 65 66 67 68 69 70	71 72 73 74 75 76 77 78 79 80

CARD TYPE - G_p(h-4) CARD-2
 CARD FUNCTION - FUEL CELL INPUT DATA
 CARD FORMAT - (2I5, 6F10.0)

NFCØP	NFCSTB	PISETI	PISET2	VJANUL(1)	VJANUL(2)	TKMXDI(1)	TKMXDI(2)	
000000	000000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000
1 2 3 4 5	6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68 69 70	71 72 73 74 75 76 77 78 79 80

CARD TYPE - G_p(h-4) CARD-3
 CARD FUNCTION - FUEL CELL INPUT DATA
 CARD FORMAT - (7F10.0)

FCVØLT	PRGRAT(1)	PRGRAT(2)	PRGTIM(1)	PRGTIM(2)	PRGINT(1)	PRGINT(2)	
000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68 69 70	71 72 73 74 75 76 77 78 79 80

NØP	SATYPE	SITYPE	SMTYPE	SPTYPE	
0 0 0 0 0 0	0 0 0 0 0 0	0 0 0 0 0 0	0 0 0 0 0 0	0 0 0 0 0 0	
1 2 3 4 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20 21	22 23 24 25	26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

SITEMP	SIPRES	SPGTEM	SØPRES	SVPRES	SHFLUX	SITHIK	FIDLØD
0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68 69 70	71 72 73 74 75 76 77 78 79 80

SULGPC	SMDIAM	SH ϕ TEM	SHDEL P	SPDEL P	SG ϕ TEM	SGGPC	SCMRAT
0 0 0 0 0 0 0 0 0 0 0 0 1 2 3 4 5 6 7 8 9 10	0 0 0 0 0 0 0 0 0 0 0 0 1 12 13 14 15 16 17 18 19 20	0 0 0 0 0 0 0 0 0 0 0 0 21 22 23 24 25 26 27 28 29 30	0 0 0 0 0 0 0 0 0 0 0 0 31 32 33 34 35 36 37 38 39 40	0 0 0 0 0 0 0 0 0 0 0 0 41 42 43 44 45 46 47 48 49 50	0 0 0 0 0 0 0 0 0 0 0 0 51 52 53 54 55 56 57 58 59 60	0 0 0 0 0 0 0 0 0 0 0 0 61 62 63 64 65 66 67 68 69 70	0 0 0 0 0 0 0 0 0 0 0 0 71 72 73 74 75 76 77 78 79 80

[illegible]

FORM LMSC 362 B-3

CARD TYPE	- G _p (i-2) CARD-5
CARD FUNCTION	- TANK GEOMETRY OPTION CARD
READ BY	- SUBROUTINE CØMPIL
CARD FORMAT	- (2I5)

CARD FORMAT																																																																															
TWØP					NØSHAP															NOT USED																																																											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

CARD TYPE	- G _p (i-3) - CARD-6
CARD FUNCTION	- TANK SEGMENT SHAPE CARD
CARD FORMAT	- (2I5, 7F10.0)

JTKTYP	JFLTYP	XD	YD	ZD	←	NOT USED	→
0 0 0 0 0 0	0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0
1 2 3 4 5	6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

NOT A CARD

NOT A CARD

NAØP					ATTYPE					AMTYPE																																																																					
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0																																																																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

ATTEMP	APRES	AHFLUX	AITHIK	AVØL	ADTAM	ANDELP	
0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68 69 70	71 72 73 74 75 76 77 78 79 80

ANBAR

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

NOT A CARD

CARD TYPE	- G _p (k) CARD-1
CARD FUNCTION	- HEAT EXCHANGER DATA INPUT CARDS
READ BY	- SUBROUTINE COMPIL
CARD FORMAT	- (I5)

NUMHEX

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

CARD TYPE	- $G_p(k)$ CARD-2	
CARD FUNCTION	- HEAT EXCHANGER DATA	
CARD FORMAT	- (11F6.0, 6X,A6)	(OXIDIZER SIDE)

HEXHIT	HEXHOT	HEXCIT	HEXCØT	HEXHIT	HEXHØT	HEXCIP	HEXCØP	HXHDLP	HXCDLP	HXMRAT		HXCØDE
0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
1 2 3 4 5 6	7 8 9 10 11 12	13 14 15 16 17 18	19 20 21 22 23 24	25 26 27 28 29 30	31 32 33 34 35 36	37 38 39 40 41 42	43 44 45 46 47 48	49 50 51 52 53 54	55 56 57 58 59 60	61 62 63 64 65 66	67 68 69 70 71 72	73 74 75 76 77 78 79

(FUEL SIDE)

[illegible]

CARD TYPE	- G _p (1) CARD-1-2	
CARD FUNCTION	- PUMP AND TURBINE INPUT DATA CARDS	
READ BY	- SUBROUTINE COMPIL	1. OXIDIZER SIDE 2. FUEL SIDE
CARD FORMAT	- (I5, 4F10.0)	

[illegible]

TPEFF										TPWPSH										TPDELP										TPWDØT																																																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

TEFF										TTEMP										TØTEMP										TMRATØ										TGGPC																																							
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0																				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

CARD FORMAT - (I5)

NUMES Ø

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

(OXIDIZER SIDE)

HSTYPE					HSMRAT					HSØITEM					HSAEE					HSPRES				
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00

(FUEL SIDE)

HSTYPE					HSMRAT					HSØTEM					HSAEE					HSPRES																																																											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

CARD TYPE	- G _p (n) CARD-1
CARD FUNCTION	- MOTOR INPUT DATA
READ BY	- SUBROUTINE COMPIL
CARD FORMAT	- (I5, 5X, 3F10.0)

[illegible]

1.2.3 Table Data Cards

The use of semi-permanent table data and the general means of acquiring such data has been previously discussed in subsection 1.1.2.1, and graphically outlined in Fig.

1.1.2.2. However, the use of an actual example will serve better to illustrate, and demonstrate, the procedure to be used in setting up tables for the users own specific applications.

The example chosen is the Electrical Heat Exchanger Heat Transfer Performance Data for Hydrogen Gas utilized in Data Table 20 of the current program table set. The data (Ref. 1) is presented in graphic form in Figure 1.2.3-1 and represents a typical data source obtained from study reports. The heat transfer coefficient as a function of hydrogen gas mass velocity, over a given range, is given for four pressures. The data is given for a one inch square section of a specific flow element diagram which is described in detail in the referenced (Ref. 1) report.

In translating curve data to table data, the limitations of computer data array manipulation must be kept in mind. Normally, if a computer independent variable is slightly off the end of a curve, the analyst simply takes a ships curve, or straight-edge and fits the curve to extend the graphic function. But a computer table look-up program will only see the first or last value in the curve point data array and (if programmed) states that the value currently considered is out of range for the table. This problem is avoided by extending (extrapolation) each curve in the set (both ends) to insure that the resulting table is adequate for the data range required in the planned analysis. For the example it was determined that the range for the independent variable (mass velocity) should be 0.1 to 6.0 lbs/hr-sq. in. The resulting points taken from the curve are given in the following table.

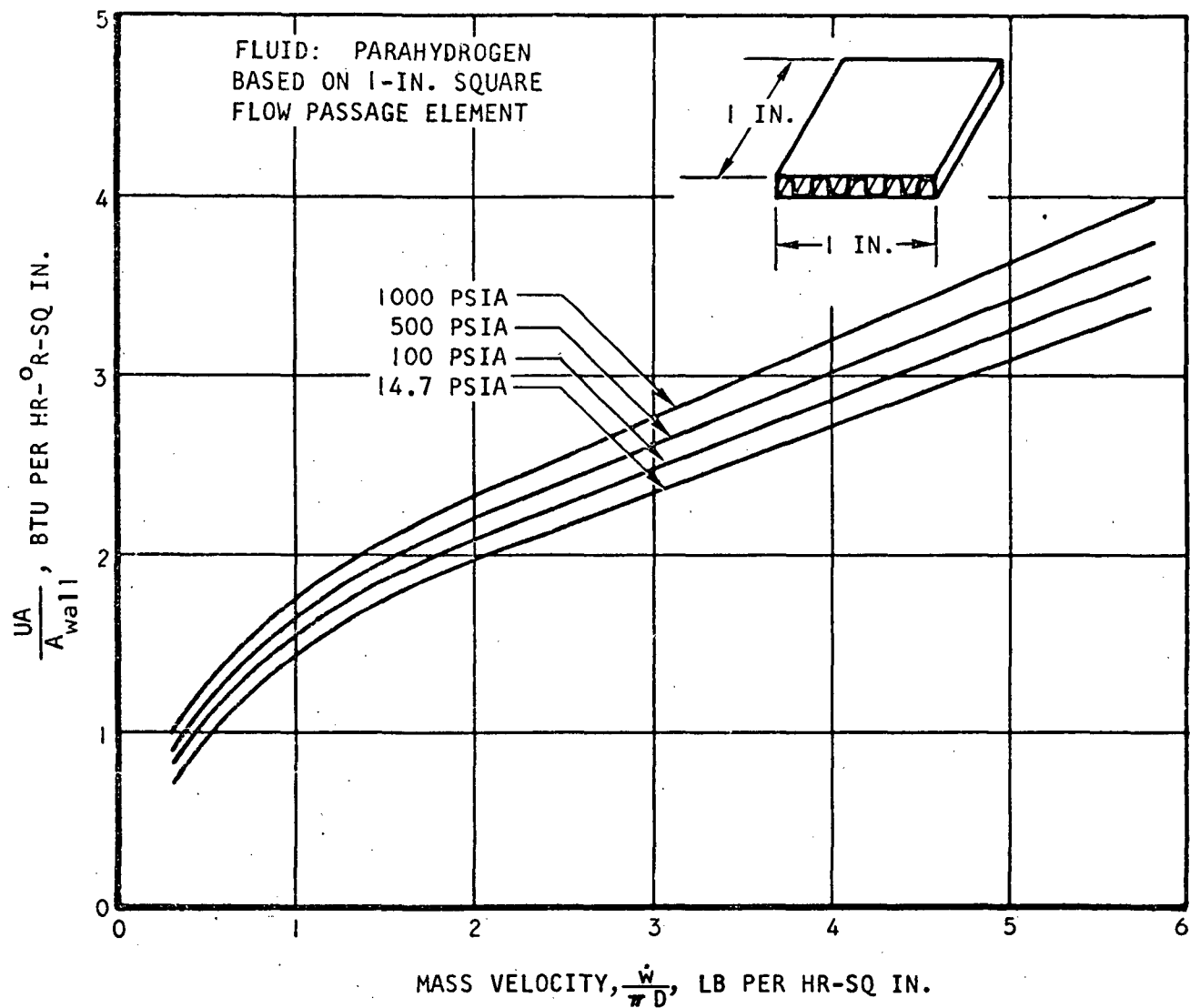


Figure 1.2.3-1 Hydrogen Electrical Heater Heat Transfer Performance

Table 1.2.3-1

**ELECTRICAL HEAT EXCHANGER - HEAT TRANSFER
PERFORMANCE FOR HYDROGEN GAS (REF. FIG. 1.2.3-1)**

Mass Velocity (lb/hr-sq. in.)	Heat Transfer Coefficient (BTU/Hr-°R-Sq. In.) at:			
	14.7 (psia)	100 (psia)	500 (psia)	1000 (psia)
0.10	.27	.35	.45	.50
0.30	.70	.78	.88	.99
0.50	.96	1.10	1.20	1.30
0.75	1.21	1.35	1.45	1.55
1.00	1.42	1.53	1.65	1.76
1.50	1.75	1.85	1.96	2.08
2.00	1.97	2.09	2.22	2.34
3.00	2.35	2.48	2.61	2.78
4.00	2.73	2.87	3.04	3.22
5.00	3.09	3.25	3.42	3.65
6.00	3.45	3.65	3.82	4.09

Translation of the data from Table 1.2.3-1 into the table data card format then consists of assigning the program variable names and values in the order illustrated in Fig. 1.2.3-2.

Taking the variables as they appear for each of the table cards shown in Figure 1.2.3-2, the following assignments are made:

Card-1, Title Card

Title = HEAT XFER.COEFF.-H2

ND = 3 (Number of variables in table)

NC = 4 (Number of command cards)

IP = (Blank) (Table will not be plotted)

NT = 20 (Table I.D. number)

CARD FUNCTION - TABLE IDENTIFICATION AND CONTROL CARD

TITLE (4A6)	ND (16)	NC (16)	IP (16)	NT (16)

CARD FUNCTION - TABLE COMMENT CARD

COMMENT
(13A6,A2)

CARD FUNCTION - TABLE SUBSET VARIABLE CARD

[illegible]

CARD FUNCTION - TABLE DATA PLOT CONTROL CARD

[illegible]

CARD FUNCTION - TABLE SUBSET DATA CARD

NV (16)	TYPE (16)	NIP (16)
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

CARD FUNCTION - TABLE DATA CARD (**DISCRETE DATA**)

XTAB (E12.0)												YTAB (E12.0)												XTAB (E12.0)												YTAB (E12.0)												XTAB (E12.0)												YTAB (E12.0)																			
0 0 0 0 0 0 0 0 0 0 0 0 0												0 0 0 0 0 0 0 0 0 0 0 0 0												0 0 0 0 0 0 0 0 0 0 0 0 0												0 0 0 0 0 0 0 0 0 0 0 0 0												0 0 0 0 0 0 0 0 0 0 0 0 0												0 0 0 0 0 0 0 0 0 0 0 0 0																			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

Card-2, Command Card

Four Command Cards are used (NC = 4). Three cards contain description of table and source data reference, while the fourth card is simply used as a spare card.

Card-3, Table Subset Variable Card

This card contains the names of the third variable in Table 1.2.3-1, the number of values the variable can take on, and the values themselves.

LABV = Pressure (psia) (Third variable)
 NP = 4 (Four pressure values)
 TAB₁ = 14.7 (First value)
 TAB₂ = 100 (Second value)
 TAB₃ = 500 (Third value)
 TAB₄ = 1000 (Fourth value)

Card-4, Table Plot Control Card

This card is used to enter the X-AXIS and Y-AXIS labels and the X value minima and maxima for plot output of table data.

LABX = MASS VELOCITY (X variable)
 LABY = HEAT TRANS. (Y variable)
 COEF.
 XMIN = 0.1 (if used)
 XMAX = 6.0 (if used)

Card-5, Table Subset Data Card

There will be a subtable of X and Y values for each value that LABV can assume. Since NP = 4, there will be four subtables arranged in the increasing order of TAB₁. Each subtable will have a Card 5 giving the number of X, Y sets of points in the subtable, the "type" of data, and the number of points to be used for interpolation.

NV = 11 (Eleven sets of X,Y values per table subset)
 TYPE = 1 (Discrete data points from curve)
 NIP = 3 (Use 3 points for interpolation since curve is somewhat parabolic)

Card-6, Table Data Card

Use 4 data cards per table-subset, entering three sets of X,Y data per card with the last card having two sets of X,Y data (NV = 11). Thus, the first table-subset card starts with Mass Velocity and Heat Transfer Coefficient values for the 14.7 psia pressure curve.

XTAB₁ = 0.10
 YTAB₁ = 0.27
 XTAB₂ = 0.30
 YTAB₂ = 0.70
 XTAB₃ = 0.50
 YTAB₃ = 0.96

The completed Table 20 is illustrated as a card listing in Table 1.2.3-2.

Table 1.2.3-2

HEAT TRANSFER PERFORMANCE DATA FOR HYDROGENDATA TABLE NUMBER 20

HT. XFER. COEF. h_2 3 4 20
 OVERALL HEAT TRANSFER COEFFICIENT FOR H₂ ELECTRIC POWERED HEX AS A
 FUNCTION OF MASS VELOCITY AND FLUID INLET PRESSURE.
 REF. AR-71-7535.

PRESSURE (PSIA)	4	14.7	100.	500.	1000.
MASVEL (LB/HR-IN) U (BTU/HR-R-SQ.IN)	3	4	20		
11 1 3					
.10	.27	.30	.70	.50	.96
.75	1.21	1.00	1.42	1.50	1.75
2.00	1.97	3.00	2.35	4.00	2.73
5.00	3.09	6.00	3.45		
11 1 3					
.10	.35	.30	.78	.50	1.10
.75	1.35	1.00	1.53	1.50	1.85
2.00	2.09	3.00	2.48	4.00	2.87
5.00	3.25	6.00	3.64		
11 1 3					
.10	.45	.30	.88	.50	1.20
.75	1.45	1.00	1.65	1.50	1.96
2.00	2.22	3.00	2.61	4.00	3.04
5.00	3.42	6.00	3.82		
11 1 3					
.10	.50	.30	.99	.50	1.30
.75	1.55	1.00	1.76	1.50	2.08
2.00	2.34	3.00	2.78	4.00	3.22
5.00	3.65	6.00	4.09		

1.2.4 Use of Program Files and Data Files

In the use of the Math Model Program as an operational analysis tool, it can be quite inconvenient to have to load the entire program, data tables, and problem deck each time a run is to be made. It is therefore recommended that the program and data tables be maintained on stored files in the facility FASTRAND drum or DISC storage.

1.2.4.1 Program File. The Math Model Program as currently structured contains approximately 16,000 source cards including the thermodynamic properties sub-programs. The program therefore is usually maintained on a master tape which takes quite awhile to read into core. It is considerably more convenient to maintain the program file on FASTRAND Drum or DISC storage and simply call in the file and copy it for use in a run.

For the UNIVAC-1108, the procedure in setting up a mass-storage file and using it are generally as follows:

Creating a Program File

Assume that the mnemonic TCIMM is used as the program file name, then the file creation cards are as follows: (A Master Tape and Program File will be created)

@ RUN	}	varies with facility operating procedures
@ LID		
@ DELETE,C	TCIMM TAPE.	(Purges tape name)
@ DELETE,C	TCIMM.	(Purges file record)
@ ASG,UP	TCIMM TAPE.,T	(Assigns tape requirement)
@ ASG,UP	TCIMM., FD4	(Assigns file on DISC)
@ PDP,IFL	CACCUM	Source Deck Cards for Entire Program
@ FØR,IS	ACCRES, ACCRES	
@ FØR,IS	ZFIND, ZFIND	

@ COPY	TPF\$. , TCIMM.	(Creates program file)
@ TIC	TCIMM. , TCIMM TAPE.	(Makes tape label)
@ CØPØUT	TCIMM. , TCIMM TAPE.	(Writes tape)
@ FREE	TCIMM TAPE.	(Frees tape)
@ FREE	TCIMM.	(Frees TCIMM file)
@ FIN or @ EØF		(Ends run)

A run is made and the Program File and Program Master Tape are created and logged in the Facility Program Library. The user is now protected in the event of a system crash which causes the loss of the stored program file since the Master Tape is a backup file.

Using the Program File

The stored Program File (TCIMM.) may be called in for use in the following fashion:

@ RUN		
@ LID		
@ ASG, A	TCIMM.	(Assigns file)
@ COPY, P	TCIMM. . TPF\$.	(Copy file to user free of core)
@ FREE	TCIMM.	(Free file to storage)

(Reference Figure 1.2.4-1)

1.2.4.2 Data Table File. Similarly, for the DATA TABLES which currently require approximately 1,300 source cards and could reach several thousand cards for newer systems, it is advisable to maintain a stored file and backup tapes. In this case a DATA file is preferred for the storage mechanism since file editing can be easily done from a DEMAND terminal, if the facility is so equipped.

The creation of a data file in the UNIVAC-1108 (EXEC-8) is accomplished as follows:

Creating a DATA File

Assume TNUMBAG. will be the file name chosen for TABLE DATA DECK.

@ RUN CARD	}	Varies with facility operating procedures
@ LID CARD		
@ DELETE,C	TNUMBAG.	(Deletes slot file
@ ASG,UP	TNUMBAG.,FO4	(Disc storage)
@ DATA,IL	TNUMBAG.	(Data processor)
<div style="border: 1px solid black; padding: 5px; display: inline-block; margin-top: 10px;"> TABLE DATA DECK FOLLOWED BY ONE BLANK CARD </div>		
@ END		
@ FIN or @ EOF		

A run is made and is listed by the Data Processor. File is now stored on disc or drum.

Using the Data File

The stored data file (TNUMBAG.) may be called in for use by placing an ASG card just before the program execution card and an ADD file card after the third card in the problem data input deck, as follows:

@ ASG,A	TNUMBAG.
@ XQT	
DATA DECK	USER CARD
	TITLE Header Card
	TABLE ECHO CONTROL CARD
@ ADD	TNUMBAG.
	SYSTEM DEFINITION CARD
	(Rest of data deck)
@ FIN or EOF	

(Reference Figure 1.2.4-1)

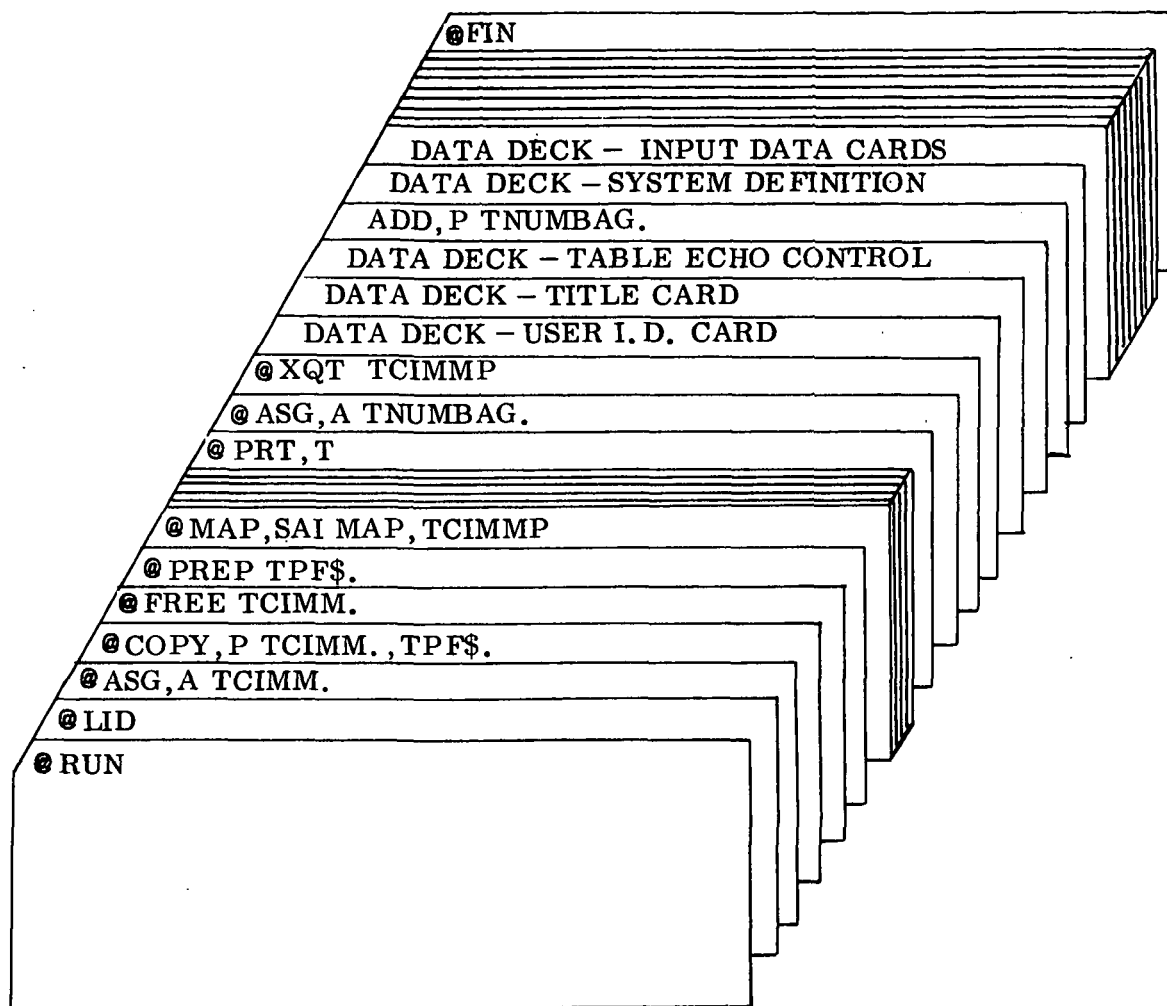


FIG. 1.2.4-1 TCIMM RUN DECK SET UP TO USE PROGRAM
FILE AND DATA TABLE FILE

1.2.4.3 Input Deck Data File. For the case where a group of analyses are desired for a given cryogen system and the "run to run" changes in the data deck are relatively few, it is often advantageous to place the input data deck into a data file and simply use change cards to alter the file when it is called in. Or, if the facility has a DEMAND system with terminals, it is possible to use the system EDITØR processor and alter the data file prior to calling it in for a run.

The use of change cards to alter the data deck is a simple procedure however, and the original Input Deck Data file can be preserved for repeated use simply by creating a temporary file containing the changes. Assume the mnemonic ACPSDATA. to be the file name for the ACPS Data Input Deck file. It is desired to change the value of NPRT2 to zero to suppress all table output on the TABLE ECHO CONTROL CARD. This requires a zero in column 20 of the card. The new file will be temporary for one run only and for this purpose use TACPS DATA. on the temporary file name.

The procedure and deck setup to be used, follows:

(a) Before the run XQT card, insert these cards:

```
@ ASG,A      ACPSDATA.
@ ASG,T      TACPSDATA.
@ DATA,L    ACPSDATA.,TACPSDATA.
-3,3
      10      1      0
```

(b) After the XQT card, and in place of a data input deck, insert this card:

```
@ ADD,P      TACPSDATA.
```

The program will now run using the temporary TACPSDATA. file, and, will list TACPSDATA. as a record of the temporary input data used in the run. The temporary file vanishes and the original unchanged file is still available for use.

1.2.5 Sample Input Data Deck Listing

As an aid in following the information presented in subsections 1.2.1 through 1.2.4, a listing of a typical Math Model data input deck is provided. The listing presented is the Attitude Control Propulsion System test problem which will be discussed in depth in Section 2.0 of this manual. Table 1.2.5-1 contains the complete test problem data input deck.

1.2.6 Data Table Deck List

The Data Tables currently employed in the program were set up to permit development and checkout of the subprograms required for the basic five types of system analysis. It, therefore, must be recognized that for systems which are more advanced, new data tables will probably be required. Direct substitution of tables is easily accomplished provided the table contains the same number of variables, arranged in the same order as used in the original table.

As an aid to future users of the program, a complete listing is presented of the current table to illustrate the diversity of table forms accommodated by the Math Model.

TABLE 1.2.5-1
ACPS INPUT DATA DECK LISTING

USERS NAME		6213		104 30235		ACPS - TEST DEMONSTRATION PROBLEM									
10	1	1	1												
0ADD	1	1	1												
ACPS	NUMBAG.	SUBCRITICAL	LAST CARD												
GAS	1	1	0											02-VAP	CONFIG 1
ENGINE	0	3	0											ENG1	CONFIG 2
LINE	10	3	0	1.0095	110.	2.0	4	.5	30.	LN01	CONFIG 3				
TEE	21	1	0	1.0095	126.3					FT01	CONFIG 4				
LINE	10	1	0	1.0095	150.0	2.0	4	.5	30.	LN02	CONFIG 5				
TAP	31	1	0	1.0095	10.5					FT02	CONFIG 6				
LINE	10	1	0	1.0095	24.0	2.0	4	.5	30.	LN03	CONFIG 7				
VALVE	31	1	0	1.0095	10.5					IV01	CONFIG 8				
LINE	10	1	0	1.0095	12.0	2.0	4	.5	30.	LN04	CONFIG 9				
VALVE	21	1	0	1.0095	135.0					CV02	CONFIG10				
LINE	10	1	0	1.0095	40.0	2.0	4	.5	30.	LN05	CONFIG11				
TAP	31	1	0	1.0095	10.5					FT03	CONFIG12				
LINE	10	1	0	1.0095	20.0	2.0	4	.5	30.	LN06	CONFIG13				
REG	32	1	0	1.0095	336.8					PR01	CONFIG14				
LINE	10	1	0	1.0095	30.0	2.0	4	.5	30.	LN07	CONFIG15				
ACCUM	0	1	0	1			4	2.0	30.	AC01	CONFIG16				
LINE	10	1	0	1.0095	24.0	2.0	4	.5	30.	LN08	CONFIG17				
HEX	1	1	0	1						HX01	CONFIG18				
GAS	1	2	0											02-LIG	CONFIG19
LINE	10	1	0	1.0180	12.0	1.0	4	.5	30.	LN09	CONFIG20				
VALVE	31	1	0	1.0180						CV01	CONFIG21				
LINE	10	1	0	1.0180	12.0	1.0	4	.5	30.	LN10	CONFIG22				
PUMP	21	1	0	1						HP01	CONFIG23				
LINE	10	1	0	1.0180	160.0	1.5	4	.5	30.	LN11	CONFIG24				
VALVE	21	1	0	1.0150	6.67					SV01	CONFIG25				
LINE	10	1	0	1.0150	12.0	2.5	4	.5	30.	LN12	CONFIG26				
TAP	31	1	0	1.0150	6.67					FT04	CONFIG27				
LINE	10	1	0	1.0150	24.0	2.5	4	.5	30.	LN13	CONFIG28				
TANK	0	1	0	2			4	2.0	30.	TK01	CONFIG29				
GAS	2	1	0											H2-VAP	CONFIG30
ENGINE	0	3	0											ENG1	CONFIG31
LINE	10	3	0	1 .011	110.	1.75	4	2.0	30.	LN21	CONFIG32				
TEE	21	1	0	1 .011	109.					FT21	CONFIG33				
LINE	10	1	0	1 .011	150.	1.75	4	2.0	30.	LN22	CONFIG34				
TAP	31	1	0	1 .011	9.					FT22	CONFIG35				
LINE	10	1	0	1 .011	24.	1.75	4	2.0	30.	LN23	CONFIG36				
VALVE	31	1	0	1 .011	9.					IV02	CONFIG37				
LINE	10	1	0	1 .011	12.	1.75	4	2.0	30.	LN24	CONFIG38				
VALVE	21	1	0	1 .011	86.					CV04	CONFIG39				
LINE	10	1	0	1 .011	40.	1.75	4	2.0	30.	LN25	CONFIG40				
TAP	31	1	0	1 .011	9.					FT23	CONFIG41				
LINE	10	1	0	1 .011	20.	1.75	4	2.0	30.	LN26	CONFIG42				
REG	32	1	0	1 .011	336.4					PR02	CONFIG43				
LINE	10	1	0	1 .011	30.	1.75	4	2.0	30.	LN27	CONFIG44				
ACCUM	0	1	0	1			4	2.0	30.	AC02	CONFIG45				
LINE	10	1	0	1 .011	24.	1.50	4	2.0	30.	LN28	CONFIG46				
HEX	1	1	0	1						HX03	CONFIG47				
GAS	2	2	0											H2-LIG	CONFIG48
LINE	10	1	0	1 .011	12.	1.50	4	2.0	30.	LN29	CONFIG49				
VALVE	31	1	0	1 .011	9.					CV03	CONFIG50				
LINE	10	1	0	1 .011	12.	1.50	4	2.0	30.	LN30	CONFIG51				

TABLE 1.2.5-1
ACPS INPUT DATA DECK LISTING (CONTD)

PUMP	21	1	0	1							HP02	CONFIG52
LINE	10	1	0	1	.018	120.	2.0	4	2.0	30.	LN31	CONFIG53
VALVE	21	1	0	1	.018	5.6					SV02	CONFIG54
LINE	10	1	0	1	.018	12.	2.0	4	2.0	30.	LN32	CONFIG55
TAP	31	1	0	1	.018	5.6					FT24	CONFIG56
LINE	10	1	0	1	.018	24.	2.0	4	2.0	30.	LN33	CONFIG57
TANK	0	1	0	2				4	2.0	30.	TK02	CONFIG58
END												ENDCFG59
4.58		540.			.9	3						DCYL01
6.15		7975.			.9	3						DCYL02
3.58		2094.			.9	3						DCYL03
38.80		536.			.9	3						DCYL04
7.43		2061.			.9	3						DCYL05
3.58		593.			.9	3						DCYL06
66.10		536.			.9	3						DCYL07
32.30		714.			.9	3						DCYL08
104.10		568.			.9	3						DCYL09
31.90		1876.			.9	3						DCYL10
16.16		571048.			.9	3						DCYL11
100.00		9584.			.9	3						DCYL12
		-1.										ENDINPUT
3	350.		400.		1750.		250.		40.		4.	ENGINE
1	1	2	2	2								SMAL.TK.02
165.		16.		170.		26.7		31.7		.2	2.	
3.		5.066										
1	1	2	2	2								SMAL.TK.H2
37.		16.		40.		19.1		24.1		.3	2.	
3.		5.										
1	0											IWOP 1 1
1	4	1										ACCUM-02
350.		2000.		.1		2.		2.5		2.05	500.	ACCUM-02
1	4	1										ACCUM-H2
350.		2000.		.2		2.		72.5		5.20	500.	ACCUM-H2
1												NUMHEX
2000.	1100.	173.	350.	245.	215.	2030.	2000.	30.	30.	1.		HX01 1
2000.	1028.	42.	350.	500.	470.	2010.	2000.	30.	10.	1.		HX03 1
2	.52		8.7	20000.		2023.						PUMP1
2	.54		1.1	70000.		2023.						PUMP2
												TRPUMP 1
												TRPUMP 2
.55	2000.		1160.		.891		250.					TURBN 1
.36	2000.		1160.		.891		500.					TURBN 2
1												NUMH80
1		1.0		2060.			245.					HSORC 1
1		1.0		2060.			500.					HSORC 2

1.2.6.1 LISTING OF DATA TABLES

DATA TABLE -1

RCS-THRUSTER WEIGHT 4 5 1
 HIGH PRESSURE APS THRUSTER
 REGEN. SLOT TYPE CU. CHAMBER
 QUAD REDUNDANT VALVES, RAD. NOZZLE
 EXPANSION RATIO SET TO 40 FOR THIS DEMONSTRATION TABLE

TU = TF (R)		2 200.	500.		
PC (PSIA)		3 100.	300.	500.	
THRUST (LB-F)		TCA WEIGHT (LB-M)			
8	1	2			
100.	19.1	300.	29.	600.	40.3
1000.	54.	1500.	70.	3000.	118.
6000.0	234.0	10000.0	475.0		
8	1	2			
100.	15.9	300.	20.9	600.	26.8
1000.	33.5	1500.	41.	3000.	64.
6000.0	118.0	10000.0	218.0		
8	1	2			
100.	15.	300.	18.9	600.	23.1
1000.	28.2	1500.	33.9	3000.	49.8
6000.0	81.0	10000.0	131.0		
8	1	2			
100.	19.1	300.	29.	600.	40.3
1000.	54.	1500.	70.	3000.	118.
6000.0	234.0	10000.0	475.0		
8	1	2			
100.	15.9	300.	20.9	600.	26.8
1000.	33.5	1500.	41.	3000.	64.
6000.0	118.0	10000.0	218.0		
8	1	2			
100.	15.	300.	18.9	600.	23.1
1000.	28.2	1500.	33.9	3000.	49.8
6000.0	81.0	10000.0	131.0		

DATA TABLE -2

RCS-VAC. SP. IMPULSE 3 4 2
 HIGH PRESSURE APS THRUSTER
 THEORETICAL PERFORMANCE FOR GASEOUS HYDROGEN/GASEOUS OXYGEN
 EXPANSION RATIO SET TO 40 FOR THIS DEMONSTRATION TABLE

PROPELLANT TEMP.		3 100.	250.	540.	
MIXTURE RATIO (O/F) ISP (LBF-SEC/LBM)					
9	1 3				
1.	360.	1.5	392.	2.	418.
2.5	435.5	3.	445.5	3.5	451.
4.	454.	5.	455.	7.	442.
9	1 3				
1.	398.	1.5	425.	2.	441.5
2.5	451.	3.	457.5	3.5	461.5
4.	463.5	5.	463.5	7.	448.
9	1 3				
1.	429.	1.5	447.	2.	459.
2.5	467.	3.	472.	3.5	474.
4.	474.	5.	470.5	7.	452.

DATA TABLE -3

SPEC.HT/LB OF O2 REMOVED 3 4 3
 SPECIFIC HEAT PER LB. OF O2 WITHDRAWN
 (SPEC. HEAT) VS (DENSITY) AT A GIVEN PRESSURE
 $DENSITY = F (PCT. WITHDRAWN, PF / (ZF * TF))$

PRESSURE (PSIA)	5	700.	1000.	1500.	2000.	3000.
PLOT LABEL						
23 1 3						
2.056	235.88	2.241	212.94	2.402	196.04	
2.590	179.47	2.811	163.24	3.285	163.24	
3.527	126.64	4.059	108.76	4.567	95.90	
5.097	85.38	7.168	59.81	8.578	50.10	
10.	44.	15.	33.7	20.	29.1	
25.	28.8	30.	31.5	35.	38.	
40.	47.5	45.	59.5	50.	75.	
60.	115.	70.126	164.			
20 1 3						
2.917	235.24	3.109	217.76	3.412	194.90	
3.784	172.64	4.254	151.02	4.871	129.96	
5.058	124.75	7.041	87.87	9.068	67.80	
10.	60.	15.	45.8	20.	39.5	
25.	37.9	30.	39.6	35.	44.8	
40.	53.5	45.	64.9	50.	80.	
60.	119.5	70.126	166.9			
17 1 3						
4.312	233.81	5.061	192.89	5.967	159.50	
7.047	132.88	8.113	114.61	9.143	101.45	
10.235	90.65	14.772	64.65	19.854	53.02	
25.	51.	30.	51.1	35.	55.	
40.	62.2	45.	72.5	50.	85.7	
60.	121.7	70.126	170.			
17 1 3						
5.657	232.12	6.046	214.14	7.022	179.50	
8.140	152.18	9.022	136.45	10.150	121.05	
12.662	97.93	15.476	82.05	19.617	68.68	
25.	64.7	30.	63.2	35.	65.3	
40.	70.9	45.	79.9	50.	90.8	
60.	126.	70.126	174.			
15 1 3						
8.185	228.51	9.205	198.44	10.240	175.72	
12.818	139.40	14.457	126.25	16.553	113.42	
20.	99.	25.	86.1	30.	81.5	
35.	82.	40.	86.9	45.	95.6	
50.	107.4	60.	137.7	70.126	180.8	

DATA TABLE -4

SPEC.HT/LB OF H2 REMOVED 3 4 4
 SPECIFIC HEAT PER LB. OF H2 WITHDRAWN
 (SPEC. HEAT) VS (DENSITY) AT A GIVEN PRESSURE
 $DENSITY = F (PCT. WITHDRAWN, PF / (ZF * TF))$

PRESSURE (PSIA)	5	300.	500.	700.	1000.	1500.
PLOT LABEL						
15 1 3						
.214	999.41	.313	565.51	.383	414.05	
.40	362.	.43	326.	.46	296.	
.5	274.	1.	151.	1.5	119.	
2.	111.	2.5	124.	3.0	153.	
3.5	192.	4.0	238.	4.365	272.	
15 1 3						
.218	1589.88	.420	786.88	.642	410.93	
.73	370.	.76	340.	.80	316.	
.86	293.	1.	245.	1.5	183.	
2.	162.	2.5	164.	3.0	185.	

3.5	217.	4.0	258.	4.365	292.
17	3				
.213	2158.33	.318	1542.80	.423	1194.40
.532	901.90	.647	674.37	.899	412.82
.98	378.	1.03	360.	1.10	348.
1.19	313.	1.5	256.	2.0	208.5
2.5	202.	3.0	217.	3.5	245.
4.0	222.	4.365	312.		
16	3				
.203	3208.73	.408	1683.98	.595	1209.78
.821	798.49	1.02	571.99	1.27	425.33
1.36	390.	1.40	378.	1.50	352.
1.55	341.	2.0	283.5	2.5	261.5
3.0	265.	3.5	284.	4.0	315.
4.365	342.				
18	3				
.254	3654.70	.415	2264.82	.614	1642.97
.815	1285.33	1.023	984.78	1.244	755.41
1.400	647.35	1.723	505.19	1.876	455.42
1.95	422.	2.00	414.	2.05	408.
2.18	391.	2.5	363.	3.0	344.5
3.5	347.5	4.0	369.	4.365	393.

DATA TABLE -5

TEMP. /LB. OF O2 REMOVED 3 4 5
 TEMPERATURE (DEG-R) PER LB. OF O2 WITHDRAWN
 (TEMP.) VS (DENSITY) AT A GIVEN PRESSURE
 DENSITY = F(PCT.WITHDRAWN,PF/(ZF)TF))

PRESSURE (PSIA	5	700.	1000.	1500.	2000.	3000.
PLOT LABEL						
21	3					
2.056	1000.	2.241	920.	2.402	860.	
2.590	800.	2.811	740.	3.285	640.	
3.527	600.	4.059	530.	4.567	480.	
5.097	440.	7.168	350.	8.578	320.	
10.209	300.	14.492	280.	18.617	276.19	
25.	276.19	36.171	276.19	44.345	270.	
51.605	255.	60.023	225.	72.252	160.	
18	3					
2.917	1000.	3.109	940.	3.412	860.	
3.784	780.	4.254	700.	4.871	620.	
5.058	600.	7.041	460.	9.069	390.	
10.000	370.	14.702	320.	21.749	300.	
26.969	295.	34.160	290.	42.970	280.	
51.612	260.	60.710	225.	72.510	160.	
15	3					
4.312	1000.	5.061	860.	5.967	740.	
7.047	640.	8.113	570.	9.143	520.	
10.235	480.	14.772	390.	19.854	350.	
25.288	330.	34.878	310.	42.293	295.	
51.137	270.	60.725	230.	72.926	160.	
15	3					
5.657	1000.	6.046	940.	7.022	820.	
8.140	720.	9.022	660.	10.150	600.	
12.662	510.	15.476	450.	19.617	400.	
26.117	360.	34.914	330.	45.084	300.	
50.769	280.	60.741	235.	72.559	165.	
12	3					
8.185	1000.	9.205	900.	10.240	820.	
12.818	680.	14.459	620.	16.553	560.	
20.909	480.	31.139	390.	41.334	340.	
51.263	295.	60.791	245.	72.618	170.	

DATA TABLE -6

TEMP. /LB. OF H2 REMOVED 3 4 6
 TEMPERATURE (DEG-R) PER LB. OF H2 WITHDRAWN
 (TEMP) VS (DENSITY) AT A GIVEN PRESSURE
 $DENSITY = F(PCT. WITHDRAWN, PF / (ZF * TF))$

PRESSURE (PSIA)	5	300.	500.	700.	1000.	1500.
PLOT LABEL						
17	3					
.214	260.0	.313	180.0	.333	150.0	
.40	148.	.43	130.	.46	124.	
.50	115.	.75	89.	1.00	78.5	
1.25	73.	1.5	69.8	2.	66.	
2.5	64.3	3.	62.	3.5	58.	
4.	51.	4.365	43.5			
16	3					
.218	420.0	.420	220.0	.642	150.0	
.73	130.	.76	127.	.80	123.5	
.85	120.	1.	107.8	1.25	95.5	
1.5	87.5	2.	79.	2.5	73.3	
3.	68.3	3.5	62.3	4.0	54.7	
4.365	48.5					
18	3					
.213	600.0	.318	400.0	.423	300.0	
.532	240.0	.647	200.0	.899	150.0	
.98	132.	1.03	128.5	1.10	123.0	
1.2	119.	1.25	116.	1.5	104.8	
2.0	90.5	2.5	80.8	3.0	74.2	
3.5	66.5	4.	58.	4.365	51.	
16	3					
.203	900.0	.408	440.0	.559	320.0	
.621	220.0	1.02	180.0	1.27	150.0	
1.36	140.5	1.40	138.0	1.50	131.0	
1.55	129.	2.	108.	2.5	94.4	
3.	84.1	3.5	74.4	4.	63.9	
4.365	55.5					
18	3					
.254	1100.	.415	650.0	.614	425.0	
.815	320.	1.023	250.0	1.244	215.0	
1.400	190.	1.723	160.	1.876	150.0	
1.95	143.0	2.0	139.0	2.05	137.0	
2.18	130.	2.5	117.	3.	101.	
3.5	86.9	4.0	73.9	4.365	65.	

DATA TABLE -7

RR/ VS PGG, M/R, PAIRB, PCHP 5 3 7
 REFERENCE REACTANT FLOW AT T.I.T. = 2060 DEG R.
 (RR) VS (PCT. I.P.) AT A GIVEN (PRES. OF GG), (MIX. RATIO), (P-AMBIENT)

PRES. GAS GEN PSIA	3	300.	600.	900.
MIXTURE RATIO	2	.5	1.0	
AMBIENT PRESSURE	2	0.	14.7	
PLOT RR/				
2	2			
0.	0.	100.	7.52	
2	2			
0.	1.23	100.	8.57	
2	2			
0.	0.	100.	9.60	
2	2			
0.	3.00	100.	10.47	
2	2			
0.	0.	100.	6.53	
2	2			
0.	.84	100.	7.13	

2	1	2		
0.	1	0.	100.	8.58
2	1	2		
0.	1	.780	100.	9.30
2	1	2		
0.	1	0.	100.	6.42
2	1	2		
0.	1	.762	100.	6.65
2	1	2		
0.	1	0.	100.	8.45
2	1	2		
0.	1	.81	100.	8.70

DATA TABLE -8

KK VS PGG, H/R, PAIR, PCMP 5 4 8
 (HH) REFERENCE REACTANT AT T.I.T. = 2060 DEG R
 KK -- CONVERSION FACTOR FOR REFERENCE REACTANT RR
 (KK) VS (PCT, HP,) AT A GIVEN (PRES OF GG), (MIX, RATIO), (P-AMBIENT)

PRES. GAS GEN PSIA	3	300.	600.	900.
MIXTURE RATIO	2	.5	1.0	
AMBIENT PRESSURE	2	0.	14.7	
PLOT KI				
2	1	2		
0.	1	1.078	100.	1.078
2	1	2		
0.	1	1.037	100.	1.069
2	1	2		
0.	1	1.062	100.	1.062
2	1	2		
0.	1	1.035	100.	1.055
2	1	2		
0.	1	1.087	100.	1.087
2	1	2		
0.	1	1.05	100.	1.082
2	1	2		
0.	1	1.067	100.	1.067
2	1	2		
0.	1	1.044	100.	1.064
2	1	2		
0.	1	1.09	100.	1.09
2	1	2		
0.	1	1.052	100.	1.088
2	1	2		
0.	1	1.068	100.	1.068
2	1	2		
0.	1	1.047	100.	1.068

DATA TABLE -9

OMS ENGINE WEIGHT 3 4 9
 ADIABATIC WALL ENGINE
 EXPANSION RATIO FIXED AT 40.
 REFERENCE - AEROJET PARAMETRIC DATA FOR LIQUID BIPROP. ENGINES, 6-2-69.

PC (PSIA)	3	100.	250.	500.	
THRUST (LB-F)		ENG.WGT. (LB-M)			
6	1	2			
200.		13.0	1500.	42.5	3000.
4500.		112.0	6000.	147.0	8000.
6	1	2			
200.		6.0	1500.	21.4	3000.
4500.		52.5	6000.	67.8	8000.
6	1	2			
200.		4.6	1500.	14.6	3000.
4500.		34.0	6000.	43.7	8000.

DATA TABLE -10

ONS VAC. SP. IMPULSE 3 4 10
PUMP FED ENGINE
EXPANSION RATIO FIXED AT 40.
REFERENCE - AEROJET PARAMETRIC DATA FOR LIQUID BIPROP. ENGINES, 6-2-69.

PC (PSIA)		3	100.	250.	500.	
MIXTURE RATIO (O/F)	ISP (LBF-SEC/LBM)					
9	1	3				
1.0		290.0	1.2	296.2	1.4	300.4
1.6		300.5	1.8	298.5	2.0	296.0
2.2		292.0	2.4	287.5	2.6	282.5
9	1	3				
1.0		293.5	1.2	302.0	1.4	308.0
1.6		309.7	1.8	310.5	2.0	308.5
2.2		306.0	2.4	301.2	2.6	299.5
9	1	3				
1.0		297.0	1.2	306.5	1.4	312.8
1.6		316.5	1.8	318.0	2.0	318.5
2.2		315.8	2.4	310.8	2.6	314.1

DATA TABLE -11

HEX HOT GAS FLOW - L02 5 8 11
HEAT EXCHANGER HOT GAS FLOW TO PROVIDE CONDITIONED OXYGEN - HIGH PRESSURE
SCALED FROM AEROJET PRESENTATION DATA OF 1/30/70

	HOT GAS SIDE	COLD GAS SIDE
TIN	2000 R	175 R
TOUT	700 R	AS SHOWN
PIN	150-250 PSIA	PARAMETER
PIN COLD (PSIA)	4 250.	650.
TOUT HOT (R)	2 500.	1000.
TOUT COLD (R)	3 200.	300.
L02 FLOW (LB/SEC)	G.G. FLOW (LB/SEC)	0.
2	0.	14.
.005928	0.	
2	0.	
.048	0.	
2	0.	
.086428	0.	
2	0.	
.005928	0.	
2	0.	
.048	0.	
2	0.	
.086428	0.	
2	0.	
.005614	0.	
2	0.	
.045428	0.	

2	0
.081857	0.
2	0
.005614	0.
2	0
.045428	0.
2	0
.081857	0.
2	0
.005114	0.
2	0
.041428	0.
2	0
.074571	0.
2	0
.005114	0.
2	0
.041428	0.
2	0
.074571	0.
2	0
.003714	0.
2	0
.030142	0.
2	0
.054142	0.
2	0
.003714	0.
2	0
.030142	0.
2	0
.054142	0.

DATA TABLE -12

HEX HOT GAS FLOW - LH2 5 8 12
 HEAT EXCHANGER HOT GAS FLOW TO PROVIDE CONDITIONED HYDROGEN - HIGH PRESSURE
 SCALED FROM AEROJET PRESENTATION DATA OF 1/30/70

	HOT GAS SIDE		COLD GAS SIDE	
TIN	2000 R		50 R	
TOUT	700 R		AS SHOWN	
PIN	150,200 PSIA		250,450 - 1200 PSIA	
PIN COLD (PSIA)	2 100.	1000.		
TOUT HOT (R)	2 500.	1000.		
TOUT COLD (R)	3 200.	300.	400.	
LH2 FLOW (LB/SEC)	G.G. FLOW (LB/SEC)	0.	14.	
2	0			
.255714	0.			
2	0			
.411428	0.			
2	0			
.599285	0.			
2	0			
.255714	0.			
2	0			
.411428	0.			
2	0			
.599285	0.			
2	0			

.255714	0.
2	0.
.411428	0.
2	0.
.594285	0.
2	0.
.255714	0.
2	0.
.411428	0.
2	0.
.594285	0.

DATA TABLE -13

GAS GENERATOR WEIGHT 4 7 13
 GAS GENERATOR ASSEMBLY WEIGHT AS A FUNCTION OF GAS GENERATOR FLOW RATE
 GAS GENERATOR ASSEMBLY WEIGHT CONSIDERS -

1. BI-PROPELLANT POPPET VALVES AND ACTUATORS WITH IGNITER
 ASSEMBLY AND EXCITER BOX AND CABLE.

2. MIXTURE RATIO OF 1.1 AND FUEL INLET TEMPERATURE OF 350 R.

TOUT (R)		2	1000.	3000.			
PC (PSIA)		5	100.	200.	250.0	300.0	500.
G.G. FLOW (LB/SEC)	G.G.A. WEIGHT (LB)						
0.	15.	2.	26.	4.	38.2		
5.	46.1	6.	58.6	7.	78.		
9.0	117.	11.0	161.	12.	179.		
0.	15.	2.	22.4	4.	30.9		
5.	36.1	6.	42.8	7.	54.9		
9.0	73.5	11.0	98.	12.	110.		
0.	15.	2.	20.1	4.	26.5		
5.	30.7	6.	37.	7.	47.6		
9.0	64.0	11.0	84.0	12.	95.0		
0.	15.	2.	19.1	4.	24.		
5.	27.4	6.	32.3	7.	40.2		
9.0	55.5	11.0	72.0	12.	81.0		
0.	15.	2.	17.6	4.	21.6		
5.	24.3	6.	28.	7.	33.4		
9.0	42.5	11.0	53.0	12.	58.5		
0.	15.	2.	26.	4.	38.2		
5.	46.1	6.	58.6	7.	78.		
9.0	117.	11.0	161.	12.	179.		
0.	15.	2.	22.4	4.	30.9		
5.	36.1	6.	42.8	7.	54.9		
9.0	73.5	11.0	98.	12.	110.		
0.	15.	2.	20.1	4.	26.5		
5.	30.7	6.	37.	7.	47.6		
9.0	64.0	11.0	84.0	12.	95.0		
0.	15.	2.	19.1	4.	24.		
5.	27.4	6.	32.3	7.	40.2		
9.0	55.5	11.0	72.0	12.	81.0		

0.	15.	2.	17.6	4.	21.6
5.	24.7	6.	28.	7.	27.4
9.0	42.5	11.0	43.0	12.	58.5

DATA TABLE -14

LH2 TRANSFER PUMP WEIGHT 5 2 14
 ***** NOTE *****
 THIS DATA IS AN APPROXIMATION ONLY AND WILL BE REPLACED
 EFFICIENCY 260. 80.
 NPSH (PSI) 20. 3.
 HEAD RISE (PSI) 25. 50.
 LH2 FLOW (LB/SEC) PUMP WEIGHT (LB)

0.	6	1	3	5.	15.	10.	25.
20.		56.		30.	110.	70.	900.
0.	6	1	3	5.	24.	10.	47.
20.		122.		30.	260.	70.	2300.
0.	6	1	3	5.	15.	10.	25.
20.		56.		30.	110.	70.	900.
0.	6	1	3	5.	24.	10.	47.
20.		122.		30.	260.	70.	2300.
0.	6	1	3	5.	15.	10.	25.
20.		56.		30.	110.	70.	900.
0.	6	1	3	5.	24.	10.	47.
20.		122.		30.	260.	70.	2300.
0.	6	1	3	5.	15.	10.	25.
20.		56.		30.	110.	70.	900.
0.	6	1	3	5.	24.	10.	47.
20.		122.		30.	260.	70.	2300.

DATA TABLE -15

LH2 TRANSFER PUMP WEIGHT 5 2 14
 ***** NOTE *****
 THIS DATA IS AN APPROXIMATION ONLY AND WILL BE REPLACED
 EFFICIENCY 260. 80.
 NPSH (PSI) 20. 3.
 HEAD RISE (PSI) 25. 50.
 LH2 FLOW (LB/SEC) PUMP WEIGHT (LB)

0.	6	1	3	5.	9.	10.	13.8
15.		19.4		20.	26.9	50.	120.
0.	7	1	3	5.	14.	10.	23.
15.		33.2		20.	47.	30.	80.25
50.0		150.0					
0.	6	1	3	5.	9.	10.	13.8
15.		19.4		20.	26.9	50.	120.
0.	7	1	3	5.	14.	10.	23.
15.		33.2		20.	47.	30.	80.25
50.0		150.0					
0.	6	1	3	5.	9.	10.	13.8

15.	19.4	20.	26.9	50.	120.
0.	5.	5.	14.	10.	23.
15.	33.2	20.	47.	30.	80.25
50.0	150.0				
0.	5.	5.	9.	10.	13.8
15.	19.4	20.	26.9	50.	120.
0.	5.	5.	14.	10.	23.
15.	33.2	20.	47.	30.	80.25
50.0	150.0				

DATA TABLE -16

MOTOR WEIGHT

3

8

16

NOTE - BRUSHLESS D-C MOTOR WEIGHT INCLUDES
ELECTRONICS (FIXED SIZE FOR EACH POWER LEVEL)

ROTOR

STATOR

BEARINGS

SHAFT

HOUSINGS

HORSEPOWER	5	1.	5.	25.	100.	200.
SHAFT SPEED (RPM)	MOTOR WEIGHT (LB)					
10	6					
2.0	+0311.8	5.0	+038.5	7.5	+035.78	
10.0	+035.28	15.0	+034.8	20.0	+034.58	
30.0	+034.39	40.0	+034.25	50.0	+034.20	
100.0	+034.20					
12	3					
2.0	+0334.2	5.0	+0327.6	7.5	+0326.05	
10.0	+0325.1	15.0	+0324.0	20.0	+0323.5	
30.0	+0322.9	40.0	+0322.4	50.0	+0322.1	
60.0	+0322.0	80.0	+0322.0	100.0	+0322.0	
9	6					
2.	+0311.1	5.	+0399.5	10.	+0394.	
15.	+0391.	20.	+0390.	30.	+0388.65	
40.	+0388.	50.	+0388.	100.	+0388.	
9	4					
2.	+03289.	5.	+03265.	10.	+03255.7	
15.	+03252.25	20.	+03250.7	30.	+03250.	
40.	+03250.	50.	+03250.	100.	+03250.	
9	5					
2.	+03502.	5.	+03462.	10.	+03440.	
15.	+03435.5	20.	+03434.	30.	+03433.	
40.	+03432.	50.	+03432.	100.	+03432.	

DATA TABLE -17

VAC.JAC.DIA.VS.WEIGHT

2

3

17

VACUUM JACKET WEIGHT AS A FUNCTION OF VACUUM JACKET DIAMETER FOR
ALUMINUM HONEYCOMB. REF. LMSC A981608.

DIAMETER (INCHES) WEIGHT (LBS)

15	3				
15.9	.396	24.0	.365	30.0	.355
36.0	.350	42.0	.360	48.0	.370
60.0	.400	72.0	.436	84.0	.478
96.0	.520	108.0	.568	120.0	.618
132.0	.660	144.0	.715	156.0	.762

DATA TABLE -18

PHI - HYDROGEN
ENERGY DERIVATIVE (PSIA-CU.FT./BTU) FOR HYDROGEN

(PHI) VS (DENSITY) AT A GIVEN PRESSURE
(DENSITY) = F(PCT.FLUID WITHDRAWN, PF/(ZF*TF))

PRESSURE (PSIA)	5	200.	400.	600.	800.	1000.
RHO (LB/CU-FT)	PHI (PSIA-CUFT/BTU)					
15	1	3				
.08097	2.028	.09797	1.923	.1434	1.912	
.209	2.494	.311	3.415	.383	3.703	
.51	3.909	.856	4.017	1.133	3.909	
2.294	3.971	3.068	6.610	3.582	8.116	
4.007	9.493	4.305	10.480	4.466	11.088	
15	1	3				
.08258	2.168	.1233	2.149	.1605	2.053	
.2304	1.299	.476	2.933	.580	3.425	
.760	3.905	1.061	4.271	1.403	4.522	
2.329	5.293	3.100	6.817	3.467	7.779	
4.085	9.616	4.349	10.484	4.498	11.040	
15	1	3				
.0743	2.122	.1232	2.180	.1578	2.184	
.2018	2.143	.2611	2.033	.3221	1.945	
.4589	2.099	.9248	3.740	1.3910	4.479	
2.3077	5.511	3.098	6.878	3.517	7.879	
3.9630	9.117	4.231	9.943	4.459	10.716	
15	1	3				
.0743	2.035	.0988	2.129	.1634	2.193	
.2090	2.201	.260	2.174	.3024	2.123	
.4517	1.973	.7367	2.519	1.1753	3.832	
1.8787	4.952	3.1546	7.010	3.6572	8.163	
3.9463	8.944	4.1993	9.696	4.421	10.420	
15	1	3				
.0743	1.931	.0927	2.040	.1832	2.197	
.2278	2.213	.2789	2.215	.3466	2.175	
.4270	2.088	.7493	2.219	1.0274	2.919	
1.9648	4.943	3.1912	7.044	3.7605	8.332	
4.0147	9.010	4.2447	9.691	4.4517	10.363	

DATA TABLE -19

TEMP. OF N2 VS RHO F(P) 3 5 19
TEMPERATURE OF NITROGEN AS A FUNCTION OF DENSITY AND PRESSURE.
F VS RHO AT GIVEN PRESSURE
REF - THERMO. PROPS. OF O2 AND N2 - PART I (N2), STEWART, JACOBSEN, MYERS,
DATED 7-31-72, UNIV. OF IDAHO, NAS9-12078 FINAL REPT.

PRESSURE	5	100.	300.	600.	800.	1000.
RHO (LB/CU-FT)	TEMP (DEG-R)					
17	1	3				
0.26024	1000.	0.32550	800.	0.37226	700.	
0.43491	600.	0.52374	500.	0.65890	400.	
0.89566	300.	1.0076	270.	1.21764	230.	
1.32607	215.	1.41267	205.	1.51513	195.	
1.76471	176.882	43.65099	176.882	47.02511	160.	
50.44270	140.	51.97474	130.			
17	1	3				
0.77626	1000.	0.97151	800.	1.11245	700.	
1.30313	600.	1.57750	500.	2.01333	400.	
2.85722	300.	3.31995	270.	4.43380	230.	
5.31260	215.	5.90023	209.176	35.37826	209.176	
41.23298	190.	45.50434	170.	49.04794	150.	
50.64242	140.	52.13136	130.			
15	1	3				

1.53854	1000.	1.92725	800.	2.21038	700.
2.59834	600.	3.17019	500.	4.12812	400.
6.32072	300.	7.95007	270.	10.36763	250.
27.95726	230.	37.27237	210.	42.17850	190.
46.06018	170.	49.40493	150.	52.35831	130.
15	1				
2.03884	1000.	2.55502	800.	2.93297	700.
3.45464	600.	4.23447	500.	5.58290	400.
9.04166	300.	12.32699	270.	19.38695	250.
32.02713	230.	38.28876	210.	42.72110	190.
46.40105	170.	49.63097	150.	52.50466	130.
15	1				
2.53271	1000.	3.17489	800.	3.64719	700.
4.30329	600.	5.29619	500.	7.06164	400.
12.07741	300.	17.61068	270.	26.07201	250.
33.93609	230.	39.12311	210.	43.21232	190.
46.72206	170.	49.84845	150.	52.64729	130.

DATA TABLE -20

HT.XFER.COEF.-H2 3 4 20
OVERALL HEAT TRANSFER COEFFICIENT FOR H2 ELECTRIC POWERED HEX AS A
FUNCTION OF MASS VELOCITY AND FLUID INLET PRESSURE.
REF. AR-71-7535.

PRESSURE (PSIA)	4	14.7	100.	500.	1000.
MASVEL (LB/HR-IN) U (BTU/HR-R-SQ.IN)					
11	3				
.10	.27	.30	.70	.50	.96
.75	1.21	1.00	1.42	1.50	1.75
2.00	1.97	3.00	2.35	4.00	2.73
5.00	3.09	6.00	3.45		
11	3				
.10	.35	.30	.78	.50	1.10
.75	1.35	1.00	1.53	1.50	1.85
2.00	2.09	3.00	2.48	4.00	2.87
5.00	3.25	6.00	3.64		
11	3				
.10	.45	.30	.88	.50	1.20
.75	1.45	1.00	1.65	1.50	1.96
2.00	2.22	3.00	2.61	4.00	3.04
5.00	3.42	6.00	3.82		
11	3				
.10	.50	.30	.99	.50	1.30
.75	1.55	1.00	1.76	1.50	2.08
2.00	2.34	3.00	2.78	4.00	3.22
5.00	3.65	6.00	4.09		

DATA TABLE -21

HT.XFER.COEF.-O2-N2 3 4 21
OVERALL HEAT TRANSFER COEFFICIENTS FOR O2 AND N2 ELECTRIC POWERED HEX
AS A FUNCTION OF MASS VELOCITY AND FLUID INLET PRESSURE.
REF. AR 71-7535

PRESSURE (PSIA)	4	14.7	100.	500.	1000.
MASVEL (LB/HR-IN) U (BTU/HR-R-SQ.IN)					
15	3				
.2	.13	.4	.17	.6	.195
.8	.22	1.0	.24	1.4	.27
2.0	.31	4.0	.40	6.0	.49
8.0	.57	12.0	.76	16.0	.935
20.	1.1	25.	1.31	30.	1.53
15	3				

.2	.14	.4	.18	.6	.205
.8	.225	1.0	.245	1.4	.285
2.0	.33	4.0	.42	6.0	.51
8.0	.595	12.0	.78	16.0	.96
20.	1.14	25.	1.35	30.	1.57
15	3				
.2	.175	.4	.22	.6	.255
.8	.27	1.0	.30	1.4	.34
2.0	.38	4.0	.495	6.0	.60
8.0	.700	12.0	.92	16.0	1.14
20.	1.35	25.	1.615	30.	1.68
15	3				
.2	.26	.4	.31	.6	.36
.8	.39	1.0	.42	1.4	.47
2.0	.52	4.0	.67	6.0	.82
8.0	.96	12.0	1.255	16.0	1.56
20.	1.635	25.	2.195	30.	2.555

DATA TABLE -22

FTU OF 321/347 ST. STEEL 2 3 22
EFFECT OF TEMPERATURE ON THE TENSILE STRENGTH OF 321/347 STAINLESS STEEL
REF. SEC. 8-LMSC A981608, PAGE 8, 1.1-8

TEMPERATURE (R)	ULT. STRENGTH (PSI)				
14	2				
36.7	266500.	59.7	251000.	159.7	207000.
259.7	173000.	359.7	143000.	459.7	121000.
559.7	108000.	659.7	91000.	859.7	75000.
1059.7	70000.	1259.7	66000.	1459.7	63000.
1659.7	50000.	1859.7	32000.		

DATA TABLE -23

FTU OF 2219-T87 ALUM. 2 3 23
EFFECT OF TEMPERATURE ON THE TENSILE STRENGTH OF 2219-T87 ALUMINUM
REF. SEC. 8-LMSC A981608, PAGE 8, 1.1-8

TEMPERATURE (R)	ULT. STRENGTH (PSI)				
16	2				
36.7	94000.	100.0	82400.	150.0	76000.
200.0	72000.	250.0	68500.	300.0	67800.
350.0	67000.	400.0	66300.	450.0	65000.
500.0	63800.	550.0	62000.	600.0	60000.
650.	58000.	859.7	38400.	1059.7	16600.
1259.7	6400.				

DATA TABLE -24

FTU OF 6061-T6 ALUMINUM 2 3 24
EFFECT OF TEMPERATURE ON THE TENSILE STRENGTH OF 6061-T6 ALUMINUM ALLOY
REF. MIL HANDBOOK -5

TEMPERATURE (R)	ULT. STRENGTH (PSI)				
13	3				
36.7	63840.	100.0	57330.	150.0	53340.
200.0	50610.	250.0	48384.	300.0	46830.
350.0	45696.	400.0	44940.	450.0	43848.
500.0	42840.	550.0	41496.	600.0	40152.
650.0	38556.				

DATA TABLE -25

FTU OF INCONEL-718 2 3 25
EFFECT OF TEMPERATURE ON THE TENSILE STRENGTH OF INCONEL-718
REF. MIL HANDBOOK -5.

TEMPERATURE (R)	ULT. STRENGTH (PSI)				
13	1	3			
36.7	219600.	100.0	213660.	150.0	210240.
200.0	206100.	250.0	201240.	300.0	196200.
350.0	193140.	400.0	189000.	450.0	185400.
500.0	182160.	550.0	179460.	600.0	177300.
650.0	175140.				

DATA TABLE -26

FTU OF TI-6AL-4V 2 3 26
EFFECT OF TEMPERATURE ON THE TENSILE STRENGTH OF TITANIUM TI-6AL-4V
REF. MIL HANDBOOK -5.

TEMPERATURE (R)	ULT. STRENGTH (PSI)				
13	1	3			
36.7	288320.	100.	261600.	150.	244480.
200.0	226880.	250.	212800.	300.	200960.
350.0	190720.	400.	181280.	450.	173120.
500.0	165280.	550.	158720.	600.	154240.
650.0	145600.				

DATA TABLE -27

HEAD COEFFICIENT VS NS 2 3 27

HEAD COEF. VS NS (SPEC. SPEED)

HEAD COEF					
15	1	2			
70.	.665	80.	.660	90.	.655
100.	.65	200.	.639	400.	.619
600.	.60	1000.	.571	2000.	.518
3000.	.472	5000.	.400	6000.	.363
7000.	.323	8000.	.281	9800.	.192

DATA TABLE -28

ADIABATIC EFF. VS NS 2 3 28

ADIABATIC EFFICIENCY VS NS (SPEC. SPEED)

ADIAB. EFF					
20	1	2			
70.	.00	80.	.03	90.	.06
100.	.08	127.	.20	200.	.30
250.	.37	300.	.44	350.	.505
400.	.555	500.	.635	600.	.695
700.	.74	800.	.77	1000.	.81
1500.	.845	2000.	.86	3000.	.875
5000.	.887	10000.	.893		

DATA TABLE -29

EFFIC. QUOT. VS IMP. DIAM 2 3 29

EFFICIENCY QUOTIENT VS IMPELLER DIAMETER

EFF. QUOT.	21	2				
.05		.0	.20	.30	.30	.42
.40		.515	.50	.60	.70	.695
.90		.755	1.20	.82	1.60	.88
2.00		.918	2.40	.945	3.20	.975
4.00		.985	5.0	.988	6.0	.991
7.0		.994	8.0	.997	9.0	.999
10.0		.9995	11.0	.9999	12.0	1.000

DATA TABLE -30

BASE LINE STAGE WT VS DI 2 3 30

BASE LINE STAGE WEIGHT VS IMPELLER DIAMETER

STAGE WT.	12	1	2			
.56		.40	.70	.415	.90	.44
1.10		.48	1.50	.63	2.0	1.02
2.50		1.72	3.5	3.8	5.0	9.0
6.00		13.80	7.0	20.0	9.0	36.2

DATA TABLE -31

SATURATED STEAM, T. VS P. 2 3 31
SATURATED WATER VAPOR - SATURATION PRESSURE AND TEMPERATURE TABLE GIVING TEMPERATURE AS A FUNCTION OF PRESSURE.

PSIAWV (PSIA)	TSATWV (DEG.R)				
21	1	2			
.08854	492.0	.12170	500.0	.20	513.14
.40	532.86	.60	545.21	.80	554.38
1.0	561.74	2.0	586.08	4.0	612.97
7.5	639.94	10.0	653.21	14.696	672.00
30.0	710.33	50.0	741.01	60.0	752.71
80.0	772.03	100.0	787.81	150.0	818.42
200.0	841.79	300.0	877.33	400.0	909.59

DATA TABLE -32

SP. HT. OF O-H COMB. PROD. 3 3 32
O/F RATIO FROM SP. HT. OF OXYGEN AND HYDROGEN COMBUSTION PRODUCTS AS A FUNCTION OF TEMPERATURE - FOR CONSTANT PRESSURE.

TEMP. - DEG.R		4 700.	1500.	2500.	3500.
O/F RATIO (RATIO)	CPBAR	(RTU/LB-R)			
12	1	3			
0.50	2.315	1.00	1.755	1.50	1.420
2.00	1.193	2.50	1.035	3.00	0.915
3.50	0.824	4.00	0.748	5.00	0.637
6.00	0.556	7.00	0.495	8.00	0.442
12	1	3			
0.50	2.420	1.00	1.845	1.50	1.705
2.00	1.270	2.50	1.098	3.00	0.980
3.50	0.892	4.00	0.817	5.00	0.703
6.00	0.626	7.00	0.561	8.00	0.512

0.50	12	1	3			
2.00		2.585	1.00	1.994	1.50	1.638
3.50		1.398	2.50	1.217	3.00	1.090
6.00		0.995	4.00	0.918	5.00	0.798
		0.717	7.00	0.658	8.00	0.608
0.50	12	1	3			
2.00		2.805	1.00	2.185	1.50	1.795
3.50		1.540	2.50	1.353	3.00	1.207
6.00		1.102	4.00	1.023	5.00	0.898
		0.810	7.00	0.758	8.00	0.710

DATA TABLE -33

OXYGEN INTERNAL ENERGY		3	2	33			
OXYGEN INTERNAL ENERGY AS A FUNCTION OF VAPOR PRESSURE ALONG ISOCHORES							
DENSITY (LB/CU FT)		5	40.	50.	60.	65.	70.
VAPOR PRESS (PSIA)		INT.ENERGY (BTU/LB)					
16	1	2					
1.		-71.576	3.	-66.661	5.		-63.982
10.		-59.824	20.	-54.901	40.		-48.963
60.		-44.881	80.	-41.650	100.		-38.920
250.		-26.086	400.	-16.568	650.		-4.123
1100.		-0.169	1400.	4.516	2000.		5.423
2600.		9.973					
14	1	2					
1.		-71.596	3.	-66.716	5.		-64.068
10.		-59.982	16.	-56.820	20.		-55.189
40.		-49.484	60.	-45.617	70.		-44.025
100.		-43.469	550.	-42.716	1200.		-41.725
1800.		-40.664	3000.	-38.575			
14	1	2					
1.		-71.594	3.	-66.709	5.		-64.056
10.		-59.961	16.	-56.789	20.		-55.150
40.		-49.415	60.	-45.518	80.		-42.462
100.		-39.901	250.	-33.400	650.		-32.411
1500.		-31.050	2600.	-28.379			
17	1	2					
1.		-71.586	3.	-66.690	5.		-64.027
10.		-59.906	16.	-56.706	20.		-55.050
40.		-49.234	60.	-45.264	80.		-42.137
100.		-39.509	250.	-27.382	400.		-18.507
700.		-15.264	1100.	-13.829	1400.		-12.766
2000.		-10.666	2600.	-8.579			
11	1	2					
1.		-71.599	3.	-66.722	5.		-64.078
10.		-60.000	16.	-56.847	20.		-55.222
40.		-54.360	200.	-54.345	1000.		-53.411
1500.		-52.714	2600.	-51.198			

DATA TABLE -34

HYDROGEN INTERNAL ENERGY		3	2	34		
HYDROGEN INTERNAL ENERGY AS A FUNCTION OF VAPOR PRESSURE ALONG ISOCHORES						
DENSITY (LB/CU FT)	5	.5	1.0	3.0	4.0	4.4
VAPOR PRESS (PSIA)	INT ENERGY (BTU/LB)					
23	1	2				
1.022	-130.455		3.00	-120.531	7.00	-106.738
12.5	-89.46	25.		-64.31	37.5	-40.23
50.	-18.76	62.5		2.34	75.	22.11
87.5	41.32	92.3		49.	100.	53.
112.5	59.5	125.		65.9	137.5	72.2
150.	78.8	162.5		85.1	175.	91.8
187.5	98.1	200.		104.6	500.	259.4
800.	580.662	1000.		768.689		

24	1	2			
1.022	-131.786	3.0	-124.043	7.0	-114.008
12.5	-102.97	25.	-85.48	37.5	-70.77
50.	-57.48	62.5	-45.16	75.	-33.52
87.5	-22.47	100.	-11.85	112.5	-1.
125.	9.47	137.5	19.48	150.	30.07
155.1	34.1	162.5	36.1	175.	39.6
187.5	42.9	200.	46.1	240.	57.0
500.	119.461	800.	197.957	1000.	271.725
24	1	2			
1.022	-132.672	3.0	-126.385	7.0	-118.855
12.5	-111.66	25.	-100.16	37.5	-91.4
50.	-83.83	62.5	-77.12	75.	-70.92
87.5	-65.1	100.	-59.58	112.5	-54.31
125.	-49.23	137.5	-44.28	150.	-39.48
151.7	-39.	162.5	-38.3	175.	-37.9
187.5	-37.1	200.	-36.3	240.	-34.2
500.	-20.858	800.	-6.132	1000.	2.862
13	1	2			
1.0	-132.784	5.0	-122.649	10.0	-115.617
20.0	-106.153	30.0	-98.897	40.0	-92.691
50.0	-87.349	100.0	-85.024	200.0	-83.497
350.	-78.572	500.	-76.946	800.	-67.869
1000.	-62.404				
13	1	2			
1.0	-132.813	3.0	-126.757	5.0	-122.774
7.0	-119.626	10.0	-115.839	15.0	-110.613
35.0	-109.632	100.0	-108.846	200.0	-105.896
350.	-102.346	500.	-99.733	800.	-93.689
1000.	-89.093				

DATA TABLE -35

OXYGEN INTERNAL ENERGY 3 3 35
 OXYGEN INTERNAL ENERGY AS A FUNCTION OF VAPOR PRESSURE ALONG ISOCHORES
 FOR LOW DENSITIES

DENSITY (LB/CU FT)	5 .1	.3	1.0	20.	40.
VAPOR PRESS (PSIA) INT. ENERGY (BTU/LB)					
5	1	2			
1.0	-50.134	5.	23.105	10.	46.217
14.696	68.129	20.	93.279		
8	1	2			
1.0	-64.464	5.	-34.285	10.	-5.399
14.696	18.785	20.	30.938	30.	46.280
40.	61.659	50.	77.295		
13	1	2			
1.0	-70.286	5.0	-58.596	10.0	-49.953
14.696	-43.418	20.0	-36.927	30.0	-26.125
40.0	-16.442	50.0	-7.469	60.0	.999
70.0	9.082	80.0	16.858	90.0	24.382
100.0	29.474				
18	1	2			
1.	-71.522	3.	-66.518	5.	-63.757
10.	-59.413	16.	-55.965	20.	-54.152
40.	-47.608	60.	-42.970	80.	-39.212
100.	-35.978	250.	-19.604	400.	-6.875
500.	0.555	700.	16.127	1100.	22.634
1400.	29.610	2000.	40.081	2600.	49.817
16	1	2			
1.	-71.576	3.	-66.661	5.	-63.982
10.	-59.824	20.	-54.901	40.	-48.963
60.	-44.881	80.	-41.650	100.	-38.920
250.	-26.086	400.	-16.568	650.	-4.123
1100.	-0.169	1400.	4.516	2000.	5.423
2600.	9.973				

DATA TABLE -36

OXYGEN VAPOR PRESSURE

3

2

36

OXYGEN VAPOR PRESSURE AS A FUNCTION OF INTERNAL ENERGY ALONG ISOCHORES
 DENSITY (LB/CU FT) 5 40. 50. 60. 65. 70.
 INT. ENERGY (BTU/LB) VAPOR PRESS (PSIA)

16	1	2				
-71.576	1.		-66.661	3.	-63.982	5.
-59.824	10.		-54.901	20.	-48.961	40.
-44.881	60.		-41.650	80.	-38.920	100.
-26.086	250.		-16.568	400.	-4.123	650.
-0.169	1100.		4.516	1400.	5.423	2000.
4.973	2600.					
17	1	2				
-71.586	1.		-66.690	3.	-64.027	5.
-59.906	10.		-56.706	16.	-55.050	20.
-44.234	40.		-45.264	60.	-42.137	80.
-34.509	100.		-27.382	250.	-18.507	400.
-15.264	700.		-13.829	1100.	-12.766	1400.
-10.666	2000.		-8.579	2600.		
14	1	2				
-71.594	1.		-66.709	3.	-64.056	5.
-59.961	10.		-56.789	16.	-55.150	20.
-44.415	40.		-45.518	60.	-42.462	80.
-34.901	100.		-33.400	250.	-32.411	650.
-31.050	1500.		-28.379	2600.		
14	1	2				
-71.596	1.		-66.716	3.	-64.068	5.
-59.982	10.		-56.820	16.	-55.189	20.
-44.484	40.		-45.617	60.	-44.025	70.
-43.469	100.		-42.716	550.	-41.725	1200.
-40.664	1800.		-38.575	3000.		
11	1	2				
-71.599	1.		-66.722	3.	-64.078	5.
-60.000	10.		-56.847	16.	-55.222	20.
-54.360	40.		-54.345	200.	-53.411	1000.
-52.717	1500.		-51.198	2600.		

DATA TABLE -37

HYDROGEN VAPOR PRESSURE

3

2

37

HYDROGEN VAPOR PRESSURE AS A FUNCTION OF INTERNAL ENERGY ALONG ISOCHORES
 DENSITY (LB/CU FT) 5 .5 1.0 3.0 4.0 4.4
 INT. ENERGY (BTU/LB) VAPOR PRESS (PSIA)

23	1	2				
-130.455	1.022		-120.531	3.0	-106.738	7.0
-89.46	12.5		-64.31	25.	-40.23	37.5
-18.76	50.		2.34	62.5	22.11	75.
41.32	87.5		49.	92.3	53.	100.
59.5	112.5		65.9	125.	72.2	137.5
78.8	150.		85.1	162.5	91.8	175.
98.1	187.5		104.6	200.	259.4	500.
580.662	800.		768.689	1000.		
24	1	2				
-131.786	1.022		-124.043	3.0	-114.008	7.0
-102.97	12.5		-85.48	25.	-70.77	37.5
-57.48	50.		-45.16	62.5	-33.52	75.
-22.47	87.5		-11.58	100.	-1.	112.5
9.47	125.		19.48	137.5	30.07	150.
34.1	155.1		36.1	162.5	39.6	175.
42.9	187.5		46.1	200.	57.	240.
119.461	500.		197.957	800.	271.725	1000.

24	1	2				
-132.672	1.022	-126.385	3.	-118.855	7.0	
-111.6	12.5	-100.16	25.	-91.4	37.5	
-83.83	50.	-77.12	62.5	-70.92	75.	
-65.1	87.5	-59.58	100.	-54.31	112.5	
-49.23	125.	-44.28	137.5	-39.48	150.	
-39.	151.7	-38.3	162.5	-37.9	175.	
-37.1	187.5	-36.3	200.	-34.2	240.	
-20.858	500.	-6.132	800.	2.862	1000.	
13	1	2				
-132.784	1.	-122.649	5.	-115.617	10.	
-106.153	20.	-93.897	30.	-92.691	40.	
-87.349	50.	-85.024	100.	-83.497	200.	
-78.572	350.	-76.946	500.	-67.869	800.	
-62.404	1000.					
13	1	2				
-132.813	1.	-126.757	3.	-122.774	5.	
-114.626	7.	-115.839	10.	-110.613	15.	
-104.632	35.	-108.846	100.	-105.896	200.	
-102.346	350.	-99.733	500.	-93.689	800.	
-84.093	1000.					

DATA TABLE -38

OXYGEN VAPOR PRESSURE 3 3 38
OXYGEN VAPOR PRESSURE AS A FUNCTION OF INTERNAL ENERGY ALONG ISOCHORES
FOR LOW DENSITIES

DENSITY	5.1	.4	1.6	20.	40.
INT. ENERGY (BTU/LB)	VAPOR PRESS (PSIA)				
5	1	2			
-50.134	1.0	23.105	5.0	46.217	10.
68.129	14.696	93.279	20.0		
8	1	2			
-64.464	1.0	-34.285	5.0	-5.399	10.
18.785	14.696	30.938	20.0	46.280	30.
61.657	40.0	77.295	50.0		
13	1	2			
-70.286	1.0	-58.596	5.0	-49.953	10.0
-43.418	14.696	-36.927	20.0	-26.125	30.0
-16.442	40.0	-7.469	50.0	.999	60.0
4.082	70.0	16.858	80.0	24.382	90.0
29.474	100.0				
18	1	2			
-71.522	1.	-66.518	3.	-63.757	5.
-54.413	10.	-55.965	16.	-54.152	20.
-47.608	40.	-42.970	60.	-39.212	80.
-35.978	100.	-19.604	250.	-6.875	400.
0.555	500.	16.127	700.	22.634	1100.
29.610	1400.	40.081	2000.	49.817	2600.
16	1	2			
-71.576	1.	-66.661	3.	-63.982	5.
-54.824	10.	-54.901	20.	-48.963	40.
-44.881	60.	-41.650	80.	-38.920	100.
-26.086	250.	-16.568	400.	-4.123	650.
-0.169	1100.	4.516	1400.	5.423	2000.
4.973	2600.				

DATA TABLE -39

ENTHALPY OF L02		2	2	39	
ENTHALPY OF SATURATED LIQUID OXYGEN - REF. NBS TN 384, 7/1/71.					
PSIA (PSIA)	H SUB L (BTU/LB)				
21	3				
.594	-73.599	1.102	-71.208	5.061	-64.007
10.009	-59.977	20.200	-55.096	40.434	-49.310
62.194	-45.093	85.013	-41.650	105.755	-39.018
157.926	-33.588	201.664	-29.809	253.498	-25.852
314.262	-21.640	348.270	-19.427	404.159	-15.937
466.319	-12.166	511.521	-9.433	559.968	-6.438
611.917	-3.028	650.000	-0.253	700.000	4.414

DATA TABLE -40

ENTHALPY OF LH2		2	0	0	40
PSIA	H SUB L				
10	3				
10.0	-115.02	20.0	-105.06	30.0	-97.32
40.0	-90.61	50.0	-84.51	60.0	-78.80
70.0	-73.35	80.0	-68.06	90.0	-62.86
100.0	-57.71				

DATA TABLE -41

ENTHALPY OF HELIUM		3	3	41			
ENTHALPY OF HELIUM AS A FUNCTION OF VAPOR PRESSURE ALONG CONSTANT TEMPERATURE, REF. NBS REPORT 9762, AUG. 1970							
TEMPERATURE (R)		5	30.	100.	200.	400.	600.
VAPOR PRESS (PSIA)	ENTHALPY (BTU/LB)						
12	2						
0.01	43.53	1.	43.51	10.	43.29		
20.	43.06	30.	42.82	40.	42.59		
50.	42.36	60.	42.13	70.	41.90		
80.	41.67	90.	41.45	100.	41.23		
12	2						
0.01	130.38	1.	130.38	10.	130.41		
20.	130.44	30.	130.47	40.	130.51		
50.	130.54	60.	130.57	70.	130.60		
80.	130.63	90.	130.66	100.	130.69		
12	2						
0.01	254.44	1.	254.45	10.	254.53		
20.	254.61	30.	254.69	40.	254.76		
50.	254.84	60.	254.92	70.	255.00		
80.	255.08	90.	255.16	100.	255.24		
12	2						
0.01	502.58	1.	502.59	10.	502.68		
20.	502.77	30.	502.87	40.	502.96		
50.	503.06	60.	503.16	70.	503.25		
80.	503.35	90.	503.44	100.	503.54		
12	2						
0.01	750.71	1.	750.72	10.	750.81		
20.	750.91	30.	751.01	40.	750.11		
50.	750.20	60.	751.30	70.	751.40		
80.	751.50	90.	751.60	100.	751.69		

DATA TABLE -42.

OXYGEN ENTHALPY (GAS) ³ ³ ⁴²
 ENTHALPY OF OXYGEN GAS AS A FUNCTION OF VAPOR PRESSURE FOR SPECIFIED
 DENSITIES. REF. NBS-TN-384, JULY 1971 AND NBS OXYGEN COMPUTER PROGRAM.

DENSITY (LB/CU FT)	5	.25	.60	1.0	1.6	2.0
VAPOR PRESS (PSIA)	ENTHALPY (BTU/LB)					
5	2					
14.696	36.146	20.0	51.865	30.0	77.698	
40.0	103.937	50.0	129.235			
6	2					
14.696	-14.958	20.0	0.450	30.0	27.309	
40.0	43.431	50.0	54.171	60.0	63.633	
9	2					
14.696	-32.084	20.0	-21.990	30.0	-4.666	
40.0	11.291	50.0	26.360	60.0	40.453	
70.0	45.781	80.0	52.173	100.0	65.269	
9	2					
14.696	-41.717	20.0	-34.612	30.0	-22.653	
40.0	-11.812	50.0	-1.682	60.0	7.943	
70.0	17.183	80.0	26.116	100.0	41.214	
9	2					
14.696	-44.928	20.0	-38.820	30.0	-28.649	
40.0	-19.513	50.0	-11.029	60.0	-3.004	
70.0	4.673	80.0	12.076	100.0	26.243	

DATA TABLE -43

HYDROGEN ENTHALPY (GAS) ³ ³ ⁴³
 ENTHALPY OF HYDROGEN GAS AS A FUNCTION OF VAPOR PRESSURE FOR SPECIFIED
 DENSITIES. REF-NBS REPORT 9288 AND 9711.

DENSITY (LB/CU FT)	5	.05	.20	.50	1.0	2.0
VAPOR PRESS (PSIA)	ENTHALPY (BTU/LB)					
10	2					
10.0	93.266	20.0	185.4	30.0	281.128	
40.0	380.721	50.0	495.624	60.0	619.830	
70.0	747.701	80.0	880.510	90.0	1022.595	
100.0	1162.921					
10	2					
15.0	34.000	20.0	45.212	30.0	57.007	
40.0	92.852	50.0	115.055	60.0	138.126	
70.0	161.610	80.0	183.764	90.0	207.222	
100.0	230.212					
10	2					
15.0	-80.643	20.0	-74.984	30.0	-43.292	
40.0	-20.679	50.0	.944	60.0	20.952	
70.0	40.356	80.0	59.747	90.0	78.699	
100.0	90.340					
10	2					
15.0	-97.193	20.	-89.093	30.	-74.273	
40.0	-60.771	50.	-48.187	60.	-36.542	
70.0	-25.279	80.	-14.324	90.	-3.629	
100.0	6.833					
10	2					
15.	-105.468	20.	-99.849	30.	-89.764	
40.	-80.817	50.	-72.753	60.	-65.289	
70.	-58.097	80.	-51.360	90.	-44.792	
100.	-38.389					

DATA TABLE -44

BETA FACTOR^{2 4 44}
CORRECTION FACTOR FOR PHITWO IN H2-O2-N2 ELECTRIC POWERER HEAT
EXCHANGER. BETA IS A FUNCTION OF CRITICAL PRESSURE RATIO.
REF. AM 71-7535.

P OVER PC	BETA					
12	1	2				
.01		.33	.1	.33	.12	.33
.20		.35	.40	.39	.60	.44
.80		.48	1.0	.52	1.4	.52
1.8		.52	2.2	.52	2.6	.52

DATA TABLE -45

SIGMA-DELTA P FOR HEXELC^{3 4 45}
PRESENTS SIGMA-DELTA P AS A FUNCTION OF MASS VELOCITY AND HEAT
EXCHANGER LENGTH.
REF. AM 71-7535.

HEX-LENGTH (IN)	5	4.	8.	16.	32.	64.
MASVEL (LB/HR-IN)	SIG-DELTA P (PSI)					
15	1	3				
.10		.000032	.20	.00011	.40	.00042
.60		.00094	.80	.00165	1.00	.0025
2.00		.0095	4.00	.0360	6.00	.075
8.00		.14	10.00	.200	20.00	.78
30.		1.6	40.00	2.8	60.00	6.0
15	1	3				
.10		.000052	.20	.00020	.40	.00078
.60		.00165	.80	.00295	1.00	.0045
2.00		.0170	4.00	.061	6.00	.140
8.00		.230	10.00	.350	20.00	1.30
30.00		2.9	40.00	4.7	60.00	10.0
15	1	3				
.10		.000098	.20	.00037	.40	.00136
.60		.0030	.80	.0050	1.00	.0080
2.00		.0295	4.00	.115	6.00	.240
8.00		.41	10.00	.64	20.00	2.40
30.00		5.0	40.00	8.5	60.00	16.00
15	1	3				
.10		.000165	.20	.00062	.40	.0024
.60		.0054	.80	.0093	1.00	.0140
2.00		.0540	4.00	.20	6.00	.43
8.00		.76	10.00	1.2	20.00	4.30
30.00		9.2	40.00	14.8	60.00	32.0
15	1	3				
.10		.0003	.20	.00113	.40	.0043
.60		.0095	.80	.0165	1.00	.0250
2.00		.092	4.00	.35	6.00	.74
8.00		1.3	10.00	2.0	20.00	7.60
30.00		14.7	40.00	26.0	60.00	57.0

DATA TABLE -46

BETA VALUES FOR H2^{3 4 46}
VOLUME EXPANSIVITY (BETA) FOR HYDROGEN AS A FUNCTION OF PRESSURE AND
TEMPERATURE.
REF. - NBS-TN-617, APRIL 1972, NAT. BUR. STANDARDS, BOULDER, COLORADO.

PRESSURE (PSIA)	5	50.0	100.0	200.0	300.0	400.0
TEMPERATURE (DEG-R)	BETA (PER DEG-R)					
13	1	2				
30.0		.0068682	36.0	.0087034	42.0	.0120937
45.406		.0154794	45.406	.0425479	60.0	.0214360
80.0		.0140154	125.0	.0082872	200.0	.0050429
340.0		.0029425	440.0	.0022710	540.0	.0018497
700.0		.0014268				

15	1	2			
30.0		.0066720	40.0	.0101009	50.0
52.072		.0305221	50.072	.0669217	54.0
60.0		.0303448	70.0	.0203346	80.0
125.0		.0085774	200.0	.0050846	340.0
440.0		.0022692	540.0	.0018476	700.0
15	1	2			
30.0		.0063024	40.0	.0091823	50.0
58.0		.0595100	60.0	.6211455	62.0
66.0		.0484820	70.0	.0336912	90.0
125.0		.0091577	200.0	.0051645	340.0
440.0		.0022652	540.0	.0018431	700.0
15	1	2			
30.0		.0059902	40.0	.0084433	50.0
60.0		.0360359	64.0	.0856922	66.0
70.0		.0683492	80.0	.0282269	90.0
125.0		.0097206	200.0	.0052391	340.0
440.0		.0022609	540.0	.0018386	700.0
15	1	2			
30.0		.0056750	40.0	.0078461	50.0
60.0		.0229678	66.0	.0428049	70.0
75.0		.0514055	85.0	.0273007	95.0
125.0		.0102432	200.0	.0053075	340.0
440.0		.0022563	540.0	.0018339	700.0

1.3 INPUT DECK SETUP

The Math Model Program has a built-in capability to process either a single system analysis run or multiple system runs. The multiple system runs can be several runs of the same system or different systems. Average system run times will vary from approximately 90 seconds (UNIVAC-1108, Exec 8) for an ACPS run to approximately 180 seconds for a fuel cell analysis.

1.3.1 Single System Deck Setup

For a single system setup the input deck setup is of the same general form as given in Fig. 1.2.4-1, where the system definition card continues the phrase, "LAST CARD" beginning in Field 4.

1.3.2 Multiple System Deck Setup

For a multiple system deck setup several adjustments are made to the input decks. First, since the Data Tables are only to be read-in once, only the first data deck will contain the ADD Card calling for Data Table input. Secondly, the System Definition card in each input deck, except the last one, will omit the phrase, "LAST CARD" (Field 4). This phrase must appear in the last deck in order to provide proper run termination. A typical multi-run deck setup is illustrated in Fig. 1.3.2-1, showing the card requirements. The illustration assumes the program and Data Tables are stored in files.

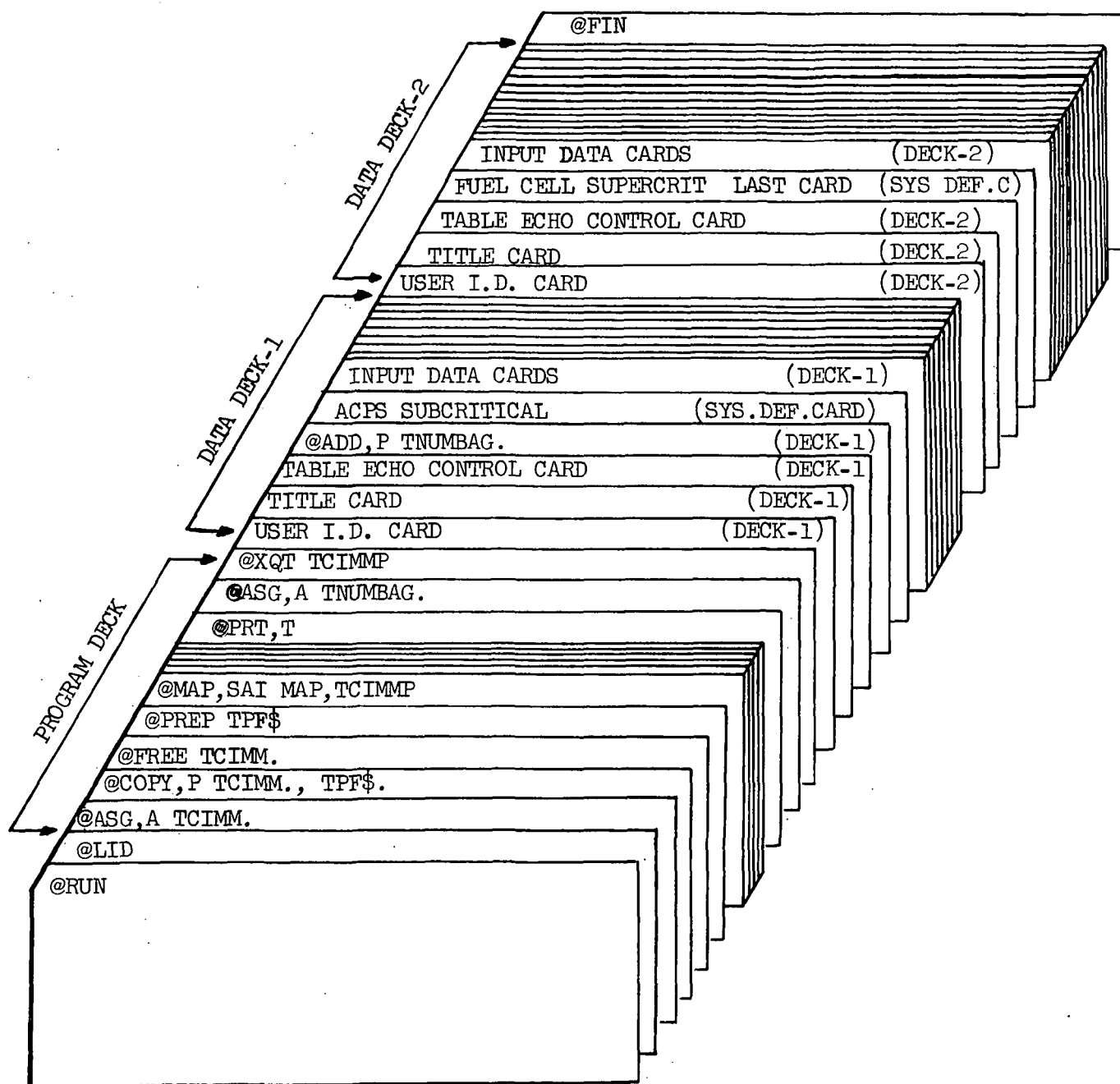


FIGURE 1.3.2-1 MULTI-SYSTEM DATA DECK

1.4 MATH MODEL PROGRAM MACHINE REQUIREMENTS

The program as it is currently configured requires in excess of 65,000 words of core storage for both the instruction and data banks. It is, therefore necessary, to either chain or overlay the program in order to avoid core overflow and truncation. Since the machine for which the program is intended is also a UNIVAC 1108 multi-processor, operating under the EXEC-8 system, the option chosen is the use of a mapped program segment overlay. A third choice, of course, is to break the large program into two or three small programs which could each process one or two of the cryogen system analyses. For specialized analysis which concentrated on, for example, the life support and fuel cell systems, it would be preferable to use only those subprograms required and reduce both core loading requirements and program run time.

The procedures required for developing a program segment overlay are documented in the UNIVAC manuals (Reference 1.4-1), describing the COLLECTOR processor. The discussion given in this manual will be limited to the program segment overlay employed for the Math Model Program.

1.4.1 Segmented Overlay Procedure

The construction of a segmented overlay for a program is accomplished by manipulation of the order in which relocatable elements are collected by the computer operating system for the production of an executable absolute element. Under the EXEC-8 operating system, this function is accomplished by the COLLECTOR, a system processor designed to provide a user with a means of gathering relocatable elements from many sources (programs) which may then be used in the construction of overlay segments in order to produce an absolute element ready for execution. Optionally, the COLLECTOR can be used to produce one relocatable element from a collection of relocatable elements. The COLLECTOR may be called explicitly by the ATMAP executive control statement, or, implicitly as a result of the user requesting execution (ATXQT) of a program which is not in the absolute form. Only absolute elements produced by the COLLECTOR can be executed.

The procedure for structuring the overlay segments involved the use of the following control statements and directives:

- (1) Setup the Entry Point Table (ATPREP)
- (2) Invoke the COLLECTOR with a ATMAP control statement.
- (3) Use the SEG directive to define each program segment in its preselected order.
- (4) Use the IN directive to call explicitly the main or subprogram assigned in each segment.
- (5) Use IN directives to call in BLOCK DATA elements where required in a segment.
- (6) Use the END directive to define the end of source language statements to be processed.

The SEG directive, or control statement is used to define the relationship and contents of segments within a program. The format employed is SEG, NAME 1, NAME 2 where NAME 1 is the name of the segment and must be specified. NAME 2 gives the names of other segments to which the segment NAME 1 is being related. The first segment named in the source input is called the main segment and is not overlayed by other segments.

The IN directive, or control statement, allows the user to include any, or all, elements from any member of files in his collection specifically in the segment named by the preceding SEG statement.

The structured collection of source statements which make up the map for the Math Model Overlay is given in Table 1.4.1-1.

Table 1.4.1-1

MATH MODEL MAP OVERLAY

```
@MAP,LAI                                MAP, TCIMMP
C    MAPPING DECK FOR TCIMM PROGRAM

      SEG MAIN
      IN CONTRL
      IN SPHTDA
      SEG LVLIA*,(MAIN)
      IN INTAB
      IN COMPIL
      SEG LVLIB*,LVLIA
      IN CRYCON
      SEG LVL2A*,(LVLIB)
      IN ACCRES
      IN LIQRES
      IN TANK
      IN VENT
      SEG LVL2B*, (LVLIB)
      IN APUSUB,APUSUP
      SEG LVL2C*, (LVLIB)
      IN ECLSS
      SEG LVL2D*, (LVLIB)
      IN FUELCL
      END
```

When the COLLECTOR precessor is invoked by means of a ATMAP control statement followed by a set of source statement mapping instructions, the collector will provide, as output, the starting addresses of all subprograms and common blocks in the order defined by the SEG and IN directives. An abbreviated illustration of segment loading addresses is given in Table 1.4.1-2.

Additionally, the collector presents a graphic representation of the segment MAP generated giving the quantity of work contained in each segment. The graphic representation generated for the Math Model Map is presented in Table 1.4.1-3.

TABLE 1.4.1-2

LOADING ADDRESSES FOR SEGMENTED OVERLAY

ADDRESS LIMITS	001000 064471	065000 154233
SEGMENT LOAD TABLE		065000 065033
INDIRECT LOAD TABLE		065034 065732
STARTING ADDRESS	011161	

WORDS DIGITAL	26426	18ANK	28316	DRANK
---------------	-------	-------	-------	-------

SEGMENT MAIN	001000 011363	065733 132600
--------------	---------------	---------------

SEGMENT LVL1A*	011364 021155	132601 134317
FOLLOWS SEGMENT MAIN		

SEGMENT LVL1B*	011364 056044	132601 151310
HAS THE SAME STARTING ADDRESS AS SEGMENT LVL1A		

SEGMENT LVL2A*	056045 063416	151311 154233
FOLLOWS SEGMENT LVL1B		

SEGMENT LVL2B*	056045 062401	151311 152114
FOLLOWS SEGMENT LVL1B		

SEGMENT LVL2C*	056045 064436	151311 153765
FOLLOWS SEGMENT LVL1B		

SEGMENT LVL2D*	056045 064471	151311 153544
FOLLOWS SEGMENT LVL1B		

TABLE 1.4.1-3
COMPUTER DRAWN OVERLAY MAP

BRANK SEGMENTS DRAWN TO SCALE: 400 WORDS DECIMAL PER DASH

MAIN (18854)

LVL1A* (847)

--

LVL1B* (7495)

LVL2A* (1491)

LVL2B* (368)

-

LVL2C* (1324)

LVL2D* (1161)

IRANK SEGMENTS DRAWN TO SCALE: 400 WORDS DECIMAL PER DASH

MAIN (4340)

LVL1A* (3962)

LVL1B* (18736)

LVL2A* (2794)

LVL2B* (2269)

LVL2C* (3321)

LVL2D* (3263)

1.5 ERROR MESSAGES

The size and relative complexity of the Math Model Program is such that the user must have some means other than the standard computer diagnostics and error messages to indicate and flag run problems.

Accordingly, several means of detecting run problems and error causing input values have been incorporated into the program itself. The two main techniques employed are out-of-range warning messages and built-in error termination. Troubleshooting the program is simplified by providing within the more sensitive subprograms, a built-in diagnostic trace technique which will output and flag intermediate values for the intermediate calculations not normally shown in the program output.

Normally, if no changes have been made in the subprogram coding, an error will usually be the result of an input data error, either as a wrong input value or the omission of the value. Since the input data decks are sometimes rather large, new decks should be very closely checked for keypunch errors and card omissions.

1.5.1 Built-In Diagnostic Trace

The built-in diagnostic trace technique consists of a set of diagnostic flag indices, a subprogram which verifies the flag and sets the "switch" position, and a set of diagnostic write statements placed in sensitive subprograms. The diagnostic flag index permits either single or multiple subprogram diagnosis as desired by the user.

1.5.1.1 The Diagnostic Flag. The diagnostic flag for any of the using subprograms is controlled through the variable "MDTRC" defined in Procedure Definition Processor CCNTRL. Input values for MDTRC are placed on the System Definition input data card described in subparagraph 1.2.2.4.

MDTRC may have a value of either zero or one, and is placed in specific system definition card positions to activate the diagnostic write statements in any of eleven (11) subprograms. The card columns utilized for MDTRC are as follows:

<u>Card Column</u>	<u>MDTRC () = DIAGNOSTIC TRACE SWITCH FOR CRYCØN (OFF = 0)</u>
(70)	(1) = 1 Turn on ACCRES
(71)	(2) = 1 Turn on ACQWT
(72)	(3) = 1 Turn on APUSUB or APUSUP
(73)	(4) = 1 Turn on CMPCAL
(74)	(5) = 1 Turn on FUELCL
(75)	(6) = 1 Turn on CØNSUM
(76)	(7) = 1 Turn on ECLSS
(77)	(8) = 1 Turn on LIQRES
(78)	(9) = 1 Turn on TANK
(79)	(10) = 1 Turn on TSIZEI
(80)	(11) = 1 Turn on WTACC

MDTRC(1) is Card Column 70, ---MDTRC(11) is Card Column 80 of the System Definition Card.

The values for MDTRC are read in the main driver routine CØNTRL and are stored in CØMMØN/CCNTRL/ for later use in the executive sequencing subroutine CRYCØN.

1.5.1.2 Diagnostic Control Subprogram. The flag MDTRC is tested in subroutine CRYCØN as each of the analytical subprograms are sequenced. If MDTRC is not zero then subroutine CRYCØN will turn ON the diagnostic switch for the subprogram being sequenced. Any other routines or functions called by this subprogram will also yield diagnostics if equipped to do so. When the diagnostic switch is ON, a function routine called DIAG is also activated and prints as output the name of the subroutine being entered and states that a diagnostic trace is in progress. Each time in the subprogram that a diagnostic write statement is encountered, DIAG is tested and if found to be activated the write statement is executed. Upon leaving the subprogram the function DIAG again states the subprogram name and the fact that the subprogram has been exited.

An illustration of the diagnostic trace output is given in Fig. 1.5-1 for a short trace used internally in the APU subprogram. The diagnostic trace was setup to be activated for an APU supercritical analysis, to examine the process of looking up ultimate strength values in Dat Table-22.

```

NAME          * * * * * PAGE 75
DFPT 6213     *      THE INTEGRATED MATH MODEL * DATE 05 FEB 73
EXT. 30235    *                                     * TIME 10:10:01
BLD. 104      *                                     * CASE 1
* * * * * AT4307 * * * * *
* * * * * TEST CASE - SUPERCRITICAL APU PROBLEM, MIXRAT=0.90 * * * * *

**DIAGNOSTIC TRACE**
FINTAB ENTRED 22      2283
FINTAB EXITED 2        4
                        .700000+03      .500000+03      .200000+03      .000000      .000000
                        .150000+04      .100000+04      .300000+03      .000000      .000000
                        .250000+04      .250000+03      .400000+03      .000000      .000000
                        .350000+04      .300000+03      .700000      .000000      .000000
                        .100000+04      .500000+03      .000000      .000000      .000000
MIPE ENTRED 1        4      .500000+03      2      3      0      0
                        .115761+06
LOCATE ENTRED 1      1 2284
LOCATE EXITED 14     1 2 2300 .367000+02      .185970+04      .266500+06      .320000+05
MIPE EXITED 2        2      1      2      1      0      0
                        .115761+06
FINTAB ENTRED 22      2283
FINTAB EXITED 2        4
                        .700000+03      .500000+03      .200000+03      .000000      .000000
                        .150000+04      .100000+04      .300000+03      .000000      .000000
                        .250000+04      .250000+03      .400000+03      .000000      .000000
                        .350000+04      .300000+03      .000000      .000000      .000000
                        .100000+04      .500000+03      .000000      .000000      .000000
MIPE ENTRED 1        4      .500000+03      2      3      0      0
                        .115761+06
LOCATE ENTRED 1      1 2284
LOCATE EXITED 14     1 2 2300 .367000+02      .185970+04      .266500+06      .320000+05
MIPE EXITED 2        2      1      2      1      0      0
                        .115761+06

```

FIGURE 1.5-1 DIAGNOSTIC TRACE ILLUSTRATIONS

Since the only subprograms having diagnostic write statements within subroutine APUSUP were subroutines FINTAB, LØCAT and the function MIPE, the table look-up procedure examination was straightforward.

As noted in Fig. 1.5-1, DIAG caused the notation DIAGNOSTIC TRACE to be printed as subroutine FINTAB was called in. DIAG noted that FINTAB was entered and Data Table-22 was found and copied. FINTAB was exited and a summary of the X-array printed out. Function MIPE was then entered followed by a call to LØCAT which was entered to locate the X,Y subtable which bracketed the desired value of 500⁰R. The array subtable limits were output and LØCAT was exited. Function MIPE then performed a linear interpolation of the X and Y arrays to obtain an ultimate stress value of 115761 psi at the desired temperature of 500⁰R for the stainless steel oxygen accumulator tank material. MIPE was then exited with the required data. The sequence was repeated a second time for the hydrogen accumulator and since operating temperature and material selection was identical to the first accumulator, the answer obtained was the same as before. In this instance, the diagnostic output was not labeled by variable name, however, in other subprograms the diagnostic data appears in variable labeled format.

Diagnostic write statements will be easily recognized in the various subprograms since they all start with an IF statement, for example:

```
IF(DIAG(0,6HFLØRAT))WRITE(IØT,6020)WDØTI, etc.
```

which says, if the diagnostic switch is turned ON, write out that FLØRAT was entered and writeout the subroutine input variables starting with flowrate, etc.

1.5.2 Error Diagnostics

In addition to the diagnostic trace for checking out program computation procedures, there are a number of Error Diagnostics built into the various subprograms which give a warning if ranges are exceeded, or if things show up out of order. For example, subroutine CMPCAL computers pressure drops and keeps track of the required system pressure as the analysis proceeds to work its way toward the supply tanks. If, upon

arriving at the tank, the subprogram finds the input tank pressure lower than the required pressure, it will reset the tank pressure equal to the calculated required pressure and print the following message:

```
"DIAGNOSTIC* TANK INPUT PRESSURE IS LESS THAN THE REQUIRED
PRESSURE. TANK PRESSURE SET = REQUIRED PRESSURE. TANK
INPUT PRESSURE = -----. REQUIRED PRESSURE = -----.
```

Similar messages warn of the failure of data to converge, or the failure of data to match preset convergence ranges.

1.5.3 Preset Error Terminations

A number of preset error terminations are provided in the program, in order to prevent the generation of meaning less data and expenditure of costly run time.

Typical conditions causing error terminations are as follows:

Errors in naming the system on the System Definition Card will always abort the run. The system name must begin with the three alpha character mnemonics specified in DATA NAMSYS given in subroutine STØDTA.

A negative temperature or pressure value will terminate the program in a number of subprograms.

A temperature or pressure out of preset ranges will terminate the program in several of the thermodynamic property subprograms.

1.5.4 Errors in Reading Table Data

Subroutine INTAB is provided with a specific set of diagnostic messages in order to permit rapid isolation of problems in the DATA TABLE input. Usually the trouble occurs during table update or replacement, however, simple card juxtaposition can also cause a lot of trouble.

The following is a list of Table Data error messages and the table data cards to examine:

- *ERROR*** THE NUMBER OF DIMENSIONS IS WRONG. ND = _____.
(See Gp(d) CARD-1).
- *ERROR*** THE NUMBER OF POINTS IS WRONG. NP = _____.
(See Gp(d) CARD-3).
- *ERROR*** THE NUMBER OF DATA POINTS IS WRONG. NV = _____.
(See Gp(d) CARD-5).
- *ERROR*** THE TABLE TYPE IS WRONG. TYPE = _____.
(See Gp(d) CARD-5).
- *DIAGNOSTIC*** THE NUMBER OF INTERPOLATION POINTS IS WRONG.
NIP = _____. NIP IS SET EQUAL TO = _____.
(See Gp(d) CARD-5).
- *ERROR*** THE ABOVE TABLE NUMBER IS LESS THAN 0 AND GREATER
THAN 50.
(See Gp(d) CARD-1 (NT)).
- *DIAGNOSTIC*** THE ABOVE TABLE HAS ALREADY BEEN INPUT. THIS TABLE
SHALL REPLACE THE PREVIOUS TABLE. (Check table
numbers-NT.)
- *ERROR*** THE TOTAL SIZE OF THE TABLES HAS EXCEEDED 7000.
THE REQUIRED SIZE IS _____. RUN TERMINATED.

Any of the foregoing messages requires action by the user to correct the Table
Data Deck or File.

1.6 PROGRAM RESTRICTIONS

Program restrictions for the current version of TCIMM are largely self-imposed by the range of the data used in cryogenic system evaluation. Array size for many of the program variables can be conveniently changed by adjustment of the PARAMETER definition statements found in each of the Procedure Definition Processors which define the common arrays. The array dimensions as currently defined, however, are adequate for current system concepts.

1.6.1 Program Analytical Range

The program currently accommodates the use of four cryogen fluids: oxygen, hydrogen, helium, and nitrogen.

Temperature ranges extend to 800°R for O₂, H₂, and He and to well over 1000°R for N₂. Pressure ranges extend to 2500 psia for O₂, H₂, and N₂. In this respect all table data ranges can be extended by simply enlarging the tables.

The configuration table will currently accommodate one hundred components and can be extended by changing the appropriate PARAMETER statement in PDP-CCNFIG.

1.6.2 Table Data Limits

Current Table Data capacity is limited to 50 tables containing a total of 7000 words. The number of tables can be changed by altering the value of the NTBN in PDP-CTAB from 50 to the desired number of tables. The total number of table words can be changed by altering the value of MXWRD in PDP-CTABA to the value desired. If MXWRD is changed, then the "error message" in FORMAT statement 6170 of sub-routine INTAB should also be changed.

1.7 TAPE AND DRUM ASSIGNMENTS

For those facilities which have limited or no mass storage capability in the form of FASTRAND or DISC program storage, tape operation will be required for Program file and Data Table file loading only. The making of the files on tape will follow whatever local procedures are used compatible with local machine requirements. The program uses no scratch or intermediate tapes or drums for data storage, hence, there will be no requirement for mounting extra tapes.

1.7.1 Data Table Tape Preparation

Provisions have been made in the program to produce and use a binary data table tape, where this is preferred over Data Table Card input, or because of mass storage limitations.

A binary data table tape can be produced in the course of a normal program run utilizing existing coding in subroutine INTAB which is controllable from the input data, "Table Data Echo Control Card" (Ref. Gp(c) CARD-1, Sub.sec. 1.2.2.2).

The variables IFT and ~~OPT~~ which occupy the first two fields of the Table Data Echo Control Card are utilized for the tape preparation and tape utilization functions.

The defined values to be used in the variables are as follows:

IF: IFT = 0	Table Data Input is from Source Cards, or Mass Storage.
IFT = 1 or 2	Table Data Input is from Binary Tape loaded from Tape Unit-15.

	IFT > 2	Table Data Input is from Binary Tape loaded from Tape Unit IFT. Where IFT specifies tape unit number (Example: IFT = 17)
IF:	$\emptyset FT = 0$	No binary data tape is to be made.
	$\emptyset FT = 1$ or 2	Binary Data Table Tape will be produced on Tape Unit - 15.
	$\emptyset FT > 2$	Binary Data Table Tape will be made on Tape Unit $\emptyset FT$. Where $\emptyset FT$ specifies Tape Unit Number (Example: $\emptyset FT = 16$)

To make a binary data tape of the Data Tables, the simplest procedure is as follows:

- (a) Assign a blank tape to be loaded in Tape Unit 15, to be reserved.
- (b) Set IFT = 0 in Table Data Echo Control Card.
- (c) Set $\emptyset FT = 1$ on Table Data Echo Control Card.
- (d) Set $\left. \begin{array}{l} NPRT = 1 \\ NPRT2 = 1 \end{array} \right\}$ To print Table Echo Summary
- (e) Load data Table Cards immediately following Table Data Echo Control Card.

The program will generate a binary data trap and those proceed with the execution of the run.

1.7.2 Data Table Tape Utilization

To use the binary data tape produced by the program, the following procedure applies:

- (a) Assign the Data Table Tape to be read in on Tape Unit 15.
- (b) Set IFT = 1 on Table Data Echo Control Card.
- (c) Set ØFT = 0 on Table Data Echo Control Card.
- (d) Set NPRT = 1 } To Print Table Echo Summary
 NPRT2 = 1 }
- (e) Omit Data Table Cards from Input Deck.

The program will now load in the Data Tables from Tape and procede to execute the run.

1.7.3 Drum and Disc Utilization

Where a facility is equipped with Drum and/or Disc file storage hardware, both the program and the Data Tables may be conveniently stored as files in mass storage. Assigning and calling in the files becomes a simple matter involving only a few control cards.

Detailed procedures for program file generation as well as DATA file generation are adequately described in the UNIVAC-1108 manuals.

Section 2

MATH MODEL SAMPLE PROBLEM

In order to illustrate the application of the Math Model Program, a sample problem for an Attitude Control Propulsion System was assembled and run. The ACPS problem was chosen because it exercises more of the major subprograms than the other systems. The sample problem graphically illustrates the conversion of the system concept schematic and supporting data into a problem data input deck and the analytical output obtained in the program run.

2.1 THE PROBLEM STATEMENT

The ACPS concept considered was chosen from among similar concepts previously studied under this contract (Ref. 2.1-1). The concept is illustrated in the schematic presented in Fig. 2.1-1. The concept is a cold helium pressurized, subcritical cryogen fluid supplied, bi-propellant gas fed propulsion system. The cryogenics are stored as fluids under low pressure and converted to gasses at high pressure through the use of high pressure liquid pumps. The high pressure liquids are vaporized in gas generator fired heat exchangers. The resulting gaseous propellants are then fed to high pressure accumulators for storage until needed for the engines. Propellant feed to the engines is through pressure regulations which drop the feed pressure to the value required for the engines. Oxygen and hydrogen gas at engine feed pressure and temperature are available to other systems via taps in the engine feed line.

The initial run of the system sample problem will establish the nominal case values for the ACPS concept and provide the base-line temperatures, pressures, pressure drops, flow rates, and component and system weights for the specified duty cycle and performance constraints. Subsequent runs of the sample case would consider the effects of perturbing the base-line input data in whatever manner is of interest to the analyst. The collected series of runs would then provide the basis for wide range performance and trade-off analysis conclusions and recommendations.

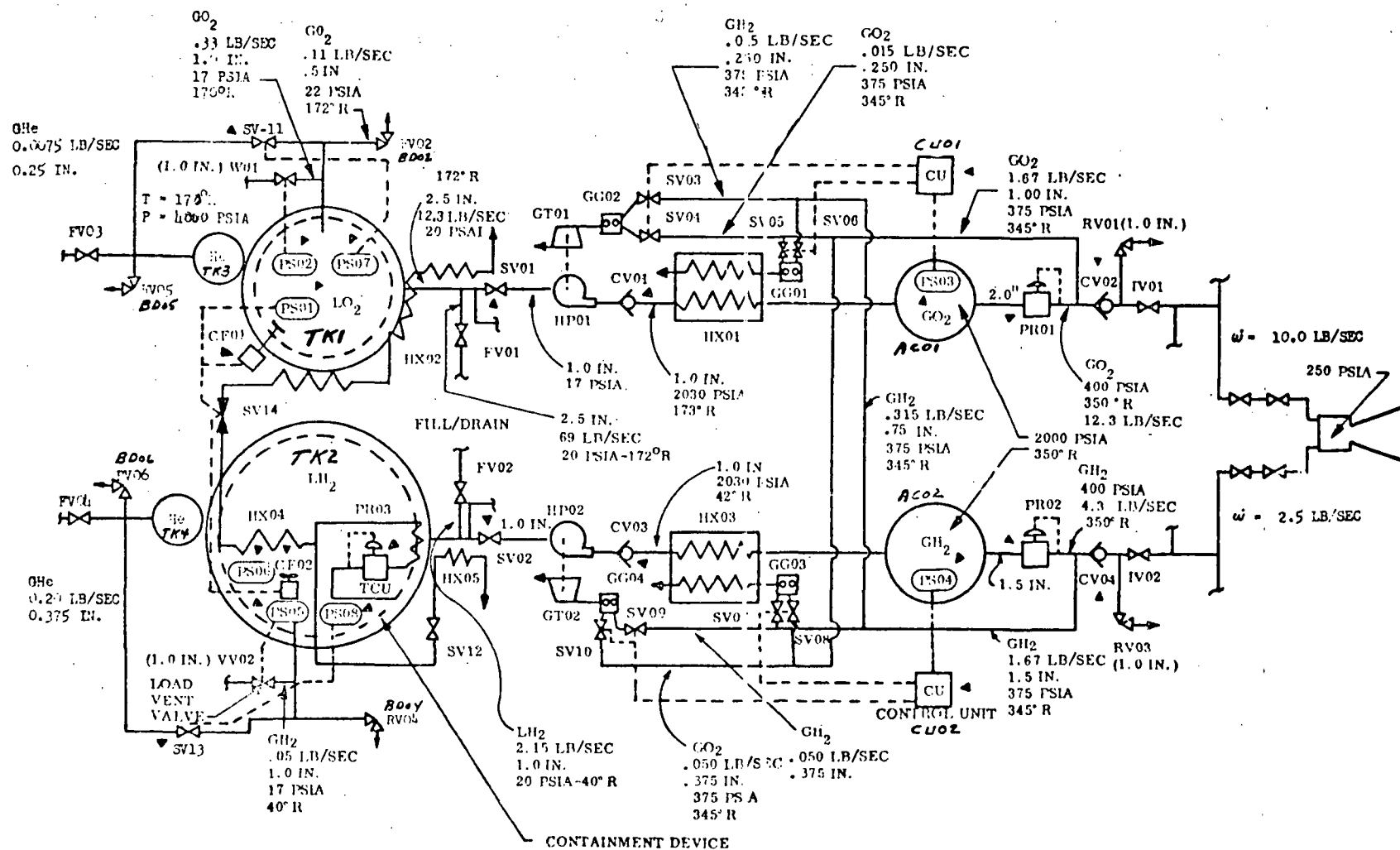
FIGURE 2.1-1

ATTITUDE CONTROL PROPULSION SYSTEM

HIGH PRESSURE - SUBCRITICAL STORAGE

STORED HELIUM PRESSURIZATION

CONCEPT 1A



142

The sample case run herein presented is the starting point, or, base-line concept analysis.

2.2 PROBLEM OUTLINE – DATA ACQUISITION

The problem outline will be provided to the analyst in the form of a preliminary study of some sort which will probably need elaboration. Specifically, the analyst will need to assure himself that the following data sources are in fact available:

- Mission Duty Cycle
- Concept Schematic
- Engine Concept Details
- Tankage Concept Details
- Heat Exchanger Requirements
- Pump and Turbine Requirements
- Gas Generator Requirements
- Subsystem Constraints
- Plumbing Layout and Approximate (at least) Line Lengths

It should not be considered unusual if the analyst finds that the data supplied is not adequate to build an input data deck and that further source interrogation is required. Assuming the required sources are available, then the task of assembling the information into the input data deck format can be accomplished. The following subparagraphs elaborate on the data reduction aspects of this task.

2.2.1 Sample System Performance and Component Data

2.2.1.1 Duty Cycle. For the ACPS sample problem a twelve burn duty cycle representative of the total burn and coast times for a typical orbiter seven day mission was selected. The duty cycle events and pertinent propellant consumption data obtained from the referenced study are presented in Table 2.2-1.

TABLE 2.2-1

ACPS DUTY CYCLE

Event	Activity	Duration (sec)	Mission Time (min.)	O ₂ -Used (lbs)	H ₂ -Used (lbs)
1	Coast-1	540 sec	0-9.0	-	-
2	Burn-1	4.58 sec	9.0-9.07	50	14
3	Coast-2	7975 sec	9.07-142.	-	-
4	Burn-2	6.15 sec	142.0-142.1	67	19
5	Coast-3	2094 sec	142.1-177	-	-
6	Burn-3	3.58	177.0-177.06	39	11
7	Coast-4	536 sec	177.06-186	-	-
8	Burn-4	38.8 sec	186.0-186.65	423	120
9	Coast-5	2061 sec	186.65-221	-	-
10	Burn-5	7.43 sec	221.0-221.12	81	23
11	Coast-6	593 sec	221.12-231	-	-
12	Burn-6	3.58 sec	231.0-231.06	39	11
13	Coast-7	536 sec	231.06-240.	-	-
14	Burn-7	66.1 sec	240.0-241.1	720	204
15	Coast-8	714 sec	241.1-253.	-	-
16	Burn-8	32.3 sec	253.0-253.54	352	100
17	Coast-9	568 sec	253.54-263.	-	-
18	Burn-9	104.1 sec.	263.0-264.74	1135	320
19	Coast-10	1876 sec.	264.74-296	-	-
20	Burn-10	31.9 sec	296.0-296.53	348	96
21	Coast-11	571,048 sec	296.53-9814.	-	-
22	Burn-11	16.16 sec	9814.0-9814.27	176	50
23	Coast-12	9584 sec	9814.27-9974	-	-
24	Burn-12	100 sec	9974.0-9975.67	1090	310
Total Deliverable				4520	1278
Total Propellant:				5798	

M.I.B. degradation: = 0.90

2.2.1.2 Engine Data. The rocket engine characteristics employed in the problem are given as follows:

Number of Engines	3
Engine Thrust	1750 lb
Engine I_{sp}	420 sec
Expansion Ratio	40:1
\emptyset/F Mixture Ratio	4:1
Propellant Inlet Temp	350 ^o R
Propellant Inlet Pressure	400 psia
Chamber Pressure	250 psia

2.2.1.3 Accumulator Data. The system requires two high pressure accumulators, one for each of the propellant gases. The accumulator characteristics employed in the sample problem are as follows:

<u>Characteristic</u>	<u>O2-Accum.</u>	<u>H2-Accum.</u>
Accumulator Code	AC01	AC02
Maximum Diameter (ft)	2.05	5.2
Volume (ft ³)	2.5	72.5
Nominal Temp (^o R)	350.	350.
Nominal Press. (psia)	2000.	2000.
Material Type	5.5.	5.5.
Insulation Type	CDAM/T.G.	CDAM/T.G.
Insulation Thickness (in.)	2.0	2.0
Est. Heal Leak Rate (Btu/hr)	0.1	0.2
Allowed Pressure Swing (psi)	500.	500.

2.2.1.4 Heat Exchanger Data. The concept requires two heat exchanger-gas generator sets for vaporization of the cryogen fluids. The heat exchanger and heat source characteristics employed in the problem are given as follows:

<u>Characteristic</u>	<u>Oxygen Side</u>	<u>Hydrogen Side</u>
Heat Exchangers:		
Heat Exchanger Code	HX01	HX03
Hot Fluid Inlet Temp ($^{\circ}\text{R}$)	2000.	2000.
Hot Fluid Outlet Temp ($^{\circ}\text{R}$)	1100.	1028.
Cold Fluid Inlet Temp ($^{\circ}\text{R}$)	173.	42.
Cold Fluid Outlet Temp ($^{\circ}\text{R}$)	350.	350.
Hot Fluid Nominal Pressure (psia)	245.	500.
Cold Fluid Nominal Pressure (psia)	2000.	2000.
Hot Side Delta-P (psi)	30.	30.
Cold Side Delta-P (psi)	30.	10.
Hot Side Nominal Flow Rate (lb/sec)	0.6	2.6
Cold Side Nominal Flow Rate (lb/sec)	12.3	4.3

Heat Source:

Type	Gas Gen	Gas Gen
O/F Mixture Ratio	1:1	1:1
Outlet Temperature ($^{\circ}\text{R}$)	2060.	2060.
Chamber Pressure (psia)	245.	500.
External Available Energy (Btu)	0.	0.

2.2.1.5 Pump and Turbine Data. Two pump and drive turbine sets are required for the concept being considered. The pump and turbine characteristics employed for the sample problem are presented as follows:

<u>Characteristic</u>	<u>Oxygen Side</u>	<u>Hydrogen Side</u>
Pump:		
Pump Code	HP01	HP02
Type	Turbo-Pump	Turbo-Pump
Pump Efficiency (%)	52.	54.

<u>Characteristic</u>	<u>Oxygen Side</u>	<u>Hydrogen Side</u>
Pump: (Cont)		
Pump NPSP (psia)	8.7	1.1
Pump Shaft Speed (rpm)	20,000	70,000
Pump Outlet Pressure (psia)	2023.	2023.
Pump Inlet Pressure (psia)	17.	17.
Pump Inlet Temperature ($^{\circ}$ R)	165.	37.
Pump Drive: - Gas Turbine		
Turbine Code	GT01	GT02
Turbine Mixture Ratio	0.891	0.891
Turbine Inlet Temperature ($^{\circ}$ R)	2000.	2000.
Turbine Delta-P (psi)	230.	480.
Turbine Delta-T ($^{\circ}$ R)	840.	840.
Turbine Efficiency (%)	55.	36.
Turbine Inlet Pressure (psia)	250.	500.

2.2.1.6 Cryogen Supply Tankage Data. One tank is required for each cryogen fluid. Initially, it is assumed that the tanks are spherical since the program will add cylindrical sections to the tanks if the fluid volume exceeds that of a sphere having an input maximum diameter.

The tankage characteristics employed in this problem are as follows:

<u>Characteristic</u>	<u>LO₂ Tank</u>	<u>LH₂ Tank</u>
Tank Material	2219-Al	2219-Al
Number of Tanks	1.	1.
Tank Code	TK01	TK02
Acquisition Device	Surf Tension	Surf Tension
Insulation Type	DGM/SN	DGM/SN
Pressurization Type	Cold He	Cold He
Fluid Initial Temp ($^{\circ}$ R)	165.	37.

<u>Characteristic</u>	<u>LO₂ Tank</u>	<u>LH₂ Tank</u>
Tank Initial Pressure (psia)	16.	16.
Pressurant Gas Temp (^o R)	170.	40.
Tank Operating Pressure (psia)	26.7	19.1
Tank Vent Pressure (psia)	31.7	24.1
Estimated Heat Leak (Btu/hr-ft ²)	0.1	0.2
Insulation Thickness (in.)	2.0	2.0
Optional Input - Fluid Loaded (lb)	(Omit)	(Omit)
Initial Percent Ullage	3.0	3.0
Tank Maximum Diameter (ft)	5.07	5.0
Tank Heat Exchanger Outlet Temp (^o R)	NA	NA
Tank Heat Exchanger Delta-P (psi)	NA	NA
Tank Circular Pump Delta-P (psi)	NA	NA
Tank Heat Exchanger -		
Gas Gen Outlet Temp (^o R)	NA	NA
Gas Gen Chamber Pressure (psia)	NA	NA
Gas Gen Mixture Ratio (ϕ /F)	NA	NA
Tank Insulation - Layers/Inch (Optional)	(Omit)	(Omit)

2.2.1.7 Lines, Controls, and Fittings Data. For the sample problem, all lines, valves and fittings are stainless steel, and are insulated where necessary with one-half inch of CDAM/TG insulation having a layer density of thirty layers per inch.

2.2.1.8 System Configuration Data. The remaining data to be assembled quite often proves to be somewhat time consuming, primarily, because in the concept stage (or, even in the early design stages) no one seems to know how long the pipes are. Therefore, one obtains a large set of vehicle drawings and proceeds to obtain approximate lengths even though they are subject to changes. The task, at hand, is to convert the system process schematic into a configuration table with a close resemblance to what the actual system will look like. This is best accomplished by detailing the data for the oxidizer side of the system first, followed by the data for the fuel side. The data

collected should be listed in the order required for data deck input. Considerable time may be saved by using 80 column keypunch worksheets with appropriately ruled and labeled columns for data collecting sheets and data card production. The basic information required for the configuration data table as derived from Fig. 1.2-1 and supporting data is presented in Tables 2.2-2 and 2.2-3. The data table will also require the use of some of the information developed for the larger components discussed in previous subsections.

2.3 PROBLEM DATA DECK

The sample problem data previously collected (subsection 2.2) can now be readied for the creation of an input data deck. Formatting information for the necessary data cards will be found in subsection 1.2.2 in the card format illustration sheets (1.2.2.1 through 1.2.2.17). The ACPS sample problem data input deck produced from the foregoing procedure is listed in Table 1.2.5-1.

Input Data Decks for other systems are created in the same general fashion as employed for the sample problem.

2.4 PROBLEM TABLE DATA REQUIREMENTS

While the data tables currently included in the Math Model Program, are adequate for the sample and test problems used for program checkout, there is no assurance that this is so for more advanced systems. Therefore, it is incumbent upon the program user to examine his system carefully for new table data requirements and make the necessary table substitutions as needed. The following tables are most likely to need either updating or the substitution of a complete new table of data:

<u>Table Number</u>	<u>Descriptive Title</u>	<u>Number of Dimensions</u>
1	RCS – Thruster Weight	4
2	RCS – Vac Sp Impulse	3
9	ØMS – Engine Weight	3
10	ØMS – Vac Sp Impulse	3

Table 2.2-2

CONFIGURATION DATA FOR ACPS - OXYGEN SIDE

Item I. D.	Item Code	Number Oper	Number Stby	Diameter (in.)	Length (in.)	Friction Factor	f (L/D)	Fluid State
Gas	Ø2-VAP							G
Engine	ENG1	3	0					G
Line	LN01	3	0	2.0	110.0	0.0095	—	G
Tee	FT01	1	0			0.0095	126.3	G
Line	LN02	1	0	2.0	150.0	0.0095		G
Tap	FT02	1	0			0.0095	10.5	G
Line	LN03	1	0	2.0	24.0	0.0095		G
Valve	IV01	1	0			0.0095	10.5	G
Line	LN04	1	0	2.0	12.0	0.0095		G
Valve	CV02	1	0			0.0095	135.0	G
Line	LN05	1	0	2.0	40.0	0.0095		G
Tap	FT03	1	0			0.0095	10.5	G
Line	LN06	1	0	2.0	20.0	0.0095		G
Reg	PR01	1	0			0.0095	336.8	G
Line	LN07	1	0	2.0	30.0	0.0095		G
Accum	AC01	1	0			NA		G
Line	LN08	1	0	2.0	24.0	0.0095		G
HEX	HX01	1	0			NA		G/L
Gas	Ø2-LIQ					NA		L
Line	LN09	1	0	1.0	12.0	0.0180		L
Valve	CV01	1	0			0.0180	65.5	L
Line	LN10	1	0	1.0	12.0	0.0180		L
Pump	HP01	1	0			NA		L
Line	LN11	1	0	1.5	160.0	0.0180		L
Valve	SV01	1	0			0.0180	6.7	L
Line	LN12	1	0	2.5	12.0	0.0180		L
Tap	FT04	1	0			0.0180	6.7	L
Line	LN13	1	0	2.5	24.0	0.0180		L
Tank	TK01	1	0			NA		L

Table 2.2-3

CONFIGURATION DATA FOR ACPS - HYDROGEN SIDE

Item I.D.	Item Code	Number Oper	Number Stby	Diameter (in.)	Length (in.)	Friction Factor	f (L/D)	Fluid State
Gas Engine	H2-VAP ENG1	3	0					G
Line	LN21	3	0	1.75	110.0	0.011	109.0	G
Tee	FT21	1	0			0.011		G
Line	LN22	1	0	1.75	150.0	0.011		G
Tap	FT22	1	0			0.011	9.0	G
Line	LN23	1	0	1.75	24.0	0.011		G
Valve	IV02	1	0			0.011	9.0	G
Line	LN24	1	0	1.75	12.0	0.011		G
Valve	CV04	1	0			0.011	86.0	G
Line	LN25	1	0	1.75	40.0	0.011		G
Tap	FT23	1	0			0.011	9.0	G
Line	LN26	1	0	1.75	20.0	0.011		G
Reg	PR02	1	0			0.011	336.4	G
Line	LN27	1	0	1.75	30.0	0.011		G
Accum	AC02	1	0					G
Line	LN28	1	0	1.50	24.0	0.011		G
HEX	HX03	1	0					G
Gas	H2-LIQ							G/L
Line	LN29	1	0	1.50	12.0	0.011		L
Valve	CV03	1	0			0.011	9.0	L
Line	LN30	1	0	1.50	12.0	0.011		L
Pump	HP02	1	0					L
Line	LN31	1	0	2.0	120.0	0.018		L
Valve	SV02	1	0			0.018	5.6	L
Line	LN32	1	0	2.0	12.0	0.018		L
Tap	FT24	1	0			0.018	5.6	L
Line	LN33	1	0	2.0	24.0	0.018		L
Tank	TK02	1	0					L
End								

<u>Table Number</u>	<u>Descriptive Title</u>	<u>Number of Dimensions</u>
11	HEX Hot Gas Flow - $L\phi_2$	5
12	HEX Hot Gas Flow - LH_2	5
13	Gas Generator Weight	4
14	$L\phi_2$ - Transfer Pump Weight	5
15	LH_2 - Transfer Pump Weight	5
16	Motor Weight (Elec)	3
17	Vac Jacket Diameter vs Weight	2

Care should be exercised in constructing the new table to insure using the same number of dimensions (variables) as in the original table, otherwise, the coding in the sub-program table-calling sequence will have to be changed for each place the table is called upon.

2.5 PROBLEM DATA OUTPUT

This subsection presents the entire output for the ACPS sample problem. The output, which follows, is indexed by page number in the header-box top left corner. This index will be used in describing the several output sections produced in the run.

2.5.1 Output Description

Page 1	<u>Table Data Input Summary</u> – Lists the tables loaded for the program run.
Page 2	<u>System Input Verification</u> – Verifies the system name called for on System Definition Card.
Pages 3, 5	<u>System Configuration and Duty Cycle Data</u> – Echo of data in Input Data Deck.
Pages 6, 11	<u>Echo of Major System Component Data</u> – From Input Data Deck.
Page 12	<u>Start of Program Calculations:</u> <u>Computed Engine Parameters</u> – Characterizes engine weight, propellant consumption and I_{sp} .
Page 13	<u>Computed Flowrate Data</u> – Presents flowrate required for subsystem cryogen consumers and total flowrate from fluid tanks.
Pages 14, 15	<u>Computed System Configuration Parameters</u> – Presents computed temperature, pressure, flowrate, flow condition and weight for each component item in system configuration.
Pages 16, 17	<u>Computed Heat Exchanger and Gas Generator Characteristic Parameters</u> – Presents summary characteristics and weight data for heat exchangers and associated gas generators.
Page 18	<u>Computed Pump and Turbine Characteristics</u> – Presents summary characteristics and weight data for pumps, turbines and turbine gas generators.
Page 19	<u>Initial Tank Sizing Calculations</u> – Presents initial tank size and weight data computed on first estimate basis.

Pages 20, 32	<u>Tank and Vent Parameter Calculations</u> – Characterizes oxygen tank history conditions for each Coast and Burn period of mission duty cycle.
Pages 33, 45	<u>Tank and Vent Parameter Calculations</u> – Characterizes hydrogen tank history conditions for each Coast and Burn period of mission duty cycle.
Page 46	<u>Final Tank Sizing Calculations</u> – Presents final tank size and weight data based upon detailed calculation of fluid requirements over integrated mission duty cycle span.
Page 47	<u>Accumulator Sizing Calculations</u> – Presents accumulator sizing and weight data computed in program.
Page 48	<u>Tank Propellant Acquisition – Device Computation</u> – Presents acquisition device computed weight, trapped propellant weight, and tank residual-propellant weight.
Page 49	<u>Component Weight Summary and System Weight Summary</u> – Presents a summary of individual component weights and corresponding insulation weights. Presents subsystem and systems weight totals.

The following pages present the detailed sample problem output.

NAME USERS NAME * * * * * PAGE 1
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:01:40
 BLD. 104 * AT4307 * CASE 1
 * * * * * ACPS - TEST DEMONSTRATION PROBLEM * * * * *

TABLE INPUT SUMMARY

TABLE NUMBER	TITLE OF TABLE	NUMBER OF DIMENSIONS	NUMBER OF SURTABLES	NUMBER OF WORDS
1	RCS-THRUSTER WEIGHT	4	6	122
2	RCS-VAC. SP. IMPULSE	3	3	68
3	SPEC.HT/LB OF O2 REMOVED	3	5	206
4	SPEC.HT/LB OF H2 REMOVED	3	5	184
5	TEMP. /LB. OF O2 REMOVED	3	5	184
6	TEMP. /LB. OF H2 REMOVED	3	5	192
7	RR/ VS PGG,M/R,PAMB,PCHP	5	12	95
8	KK VS PGG,M/R,PAMB,PCHP	5	12	95
9	ONS ENGINE WEIGHT	3	3	50
10	ONS VAC. SP. IMPULSE	3	3	68
11	HEX HOT GAS FLOW - LO2	5	24	133
12	HEX HOT GAS FLOW - LH2	5	12	71
13	GAS GENERATOR WEIGHT	4	10	220
14	LO2 TRANSFER PUMP WEIGHT	5	8	130
15	LH2 TRANSFER PUMP WEIGHT	5	8	138
16	MOTOR WEIGHT	3	5	120
17	VAC,JAC,DIA.VS.WEIGHT	2	1	34
18	PHI - HYDROGEN	3	5	172
19	TEMP. OF H2 VS RHO F(P)	3	5	180
20	HT.XFER.COEF.-H2	3	4	106
21	HT.XFER.COEF.-O2-N2	3	4	138
22	FTU OF 321/347 ST.STEEL	2	1	32
23	FTU OF 2219-T87 ALUM.	2	1	36
24	FTU OF 6061-T6 ALUMINUM	2	1	30
25	FTU OF INCONEL-718	2	1	30
26	FTU OF TI-6AL-4V	2	1	30
27	HEAD COEFFICIENT VS NS	2	1	34
28	ADIABATIC EFF. VS NS	2	1	44
29	EFFIC. QUOT.VS IMP. DIAM	2	1	46
30	BASE LINE STAGE WT VS DI	2	1	28
31	SATURATED STEAM. T.VS P.	2	1	46
32	SP.HT. OF O-H COMB.PROD.	3	4	114
33	OXYGEN INTERNAL ENERGY	3	5	166
34	HYDROGEN INTERNAL ENERGY	3	5	216
35	OXYGEN INTERNAL ENERGY	3	5	142
36	OXYGEN VAPOR PRESSURE	3	5	166
37	HYDROGEN VAPOR PRESSURE	3	5	216
38	OXYGEN VAPOR PRESSURE	3	5	142
39	ENTHALPY OF LO2	2	1	46
40	ENTHALPY OF LH2	2	1	24
41	ENTHALPY OF HELIUM	3	5	142
42	OXYGEN ENTHALPY (GAS)	3	5	98
43	HYDROGEN ENTHALPY (GAS)	3	5	122
44	BETA FACTOR	2	1	28
45	SIGNA-DELTAP FOR HEXELC	3	5	172
46	BETA VALUES FOR H2	3	5	168

TOTAL TABLE STORAGE = 5024

NAME USERS NAME ***** PAGE 2
DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
EXT. 30235 * * TIME 15:01:49
BLD. 104 * AT4307 * CASE 1

ACPS - TEST DEMONSTRATION PROBLEM

*** YOU HAVE CALLED FOR THE SYSTEM ACPS ***

NAME USERS NAME * * * * * PAGE 3
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:01:49
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

***** SYSTEM CONFIGURATION *****

COMP NAME	COMP CODE	FUNC. TYPE	NUMB. OPER.	NUMB. STBY.	MATRL. TYPE	FLOW COEFFICIENT	FRICTION	LINE LENGTH OR L-OVER-D	LINE DIAMETER	INSULATION TYPE	INSULATION THICKNESS	NO. LAYERS INSULATION
GAS	02-VAP	1	1	0	0	.00000000		.00	.00	0	.00	.0
ENGINE	ENG1	0	3	0	0	.00000000		.00	.00	0	.00	.0
LINE	LN01	10	3	0	1	.95000000-02		110.00	2.00	4	.50	30.0
TEE	FT01	21	1	0	1	.95000000-02		126.30	.00	0	.00	.0
LINE	LN02	10	1	0	1	.95000000-02		150.00	2.00	4	.50	30.0
TAP	FT02	31	1	0	1	.95000000-02		10.50	.00	0	.00	.0
LINE	LN03	10	1	0	1	.95000000-02		24.00	2.00	4	.50	30.0
VALVE	IV01	31	1	0	1	.95000000-02		10.50	.00	0	.00	.0
LINE	LN04	10	1	0	1	.95000000-02		12.00	2.00	4	.50	30.0
VALVE	CV02	21	1	0	1	.95000000-02		135.00	.00	0	.00	.0
LINE	LN05	10	1	0	1	.95000000-02		40.00	2.00	4	.50	30.0
TAP	FT03	31	1	0	1	.95000000-02		10.50	.00	0	.00	.0
LINE	LN06	10	1	0	1	.95000000-02		20.00	2.00	4	.50	30.0
REG	PR01	32	1	0	1	.95000000-02		336.80	.00	0	.00	.0
LINE	LN07	10	1	0	1	.95000000-02		30.00	2.00	4	.50	30.0
ACCUM	AC01	0	1	0	1	.00000000		.00	.00	4	2.00	30.0
LINE	LN08	10	1	0	1	.95000000-02		24.00	2.00	4	.50	30.0
HEX	HX01	1	1	0	1	.00000000		.00	.00	0	.00	.0
GAS	02-LIQ	1	2	0	0	.00000000		.00	.00	0	.00	.0
LINE	LN09	10	1	0	1	.18000000-01		12.00	1.00	4	.50	30.0
VALVE	CV01	31	1	0	1	.18000000-01		.00	.00	0	.00	.0
LINE	LN10	10	1	0	1	.18000000-01		12.00	1.00	4	.50	30.0
PUMP	NP01	21	1	0	1	.00000000		.00	.00	0	.00	.0
LINE	LN11	10	1	0	1	.18000000-01		160.00	1.50	4	.50	30.0
VALVE	SV01	21	1	0	1	.15000000-01		6.67	.00	0	.00	.0
LINE	LN12	10	1	0	1	.15000000-01		12.00	2.50	4	.50	30.0
TAP	FT04	31	1	0	1	.15000000-01		6.67	.00	0	.00	.0
LINE	LN13	10	1	0	1	.15000000-01		24.00	2.50	4	.50	30.0
TANK	TK01	0	1	0	2	.00000000		.00	.00	4	2.00	30.0
GAS	02-VAP	2	1	0	0	.00000000		.00	.00	0	.00	.0
ENGINE	ENG1	0	3	0	0	.00000000		.00	.00	0	.00	.0
LINE	LN21	10	3	0	1	.11000000-01		110.00	1.75	4	2.00	30.0
TEE	FT21	21	1	0	1	.11000000-01		109.00	.00	0	.00	.0
LINE	LN22	10	1	0	1	.11000000-01		150.00	1.75	4	2.00	30.0
TAP	FT22	31	1	0	1	.11000000-01		9.00	.00	0	.00	.0
LINE	LN23	10	1	0	1	.11000000-01		24.00	1.75	4	2.00	30.0
VALVE	IV02	31	1	0	1	.11000000-01		9.00	.00	0	.00	.0
LINE	LN24	10	1	0	1	.11000000-01		12.00	1.75	4	2.00	30.0
VALVE	CV04	21	1	0	1	.11000000-01		86.00	.00	0	.00	.0
LINE	LN25	10	1	0	1	.11000000-01		40.00	1.75	4	2.00	30.0
TAP	FT23	31	1	0	1	.11000000-01		9.00	.00	0	.00	.0
LINE	LN26	10	1	0	1	.11000000-01		20.00	1.75	4	2.00	30.0
REG	PR02	32	1	0	1	.11000000-01		336.40	.00	0	.00	.0
LINE	LN27	10	1	0	1	.11000000-01		30.00	1.75	4	2.00	30.0
ACCUM	AC02	0	1	0	1	.00000000		.00	.00	4	2.00	30.0

NAME USERS NAME * * * * * PAGE 4
 DEFT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:01:50
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

***** SYSTEM CONFIGURATION *****

COMP NAME	COMP CODE	FUNC. TYPE	NUMB. OPER.	NUMB. STBY.	MATRL. TYPE	FLOW FRICTION COEFFICIENT	LINE LENGTH OR L-OVER-D	LINE DIAMETER	INSULATION TYPE	INSULATION THICKNESS	NO. LAYERS INSULATION
LINE	LN28	10	1	0	1	.11000000-01	24.00	1.50	4	2.00	30.0
HEX	HX03	1	1	0	1	.00000000	.00	.00	0	.00	.0
GAS	H2-LIQ	2	2	0	0	.00000000	.00	.00	0	.00	.0
LINE	LN29	10	1	0	1	.11000000-01	12.00	1.50	4	2.00	30.0
VALVE	CV03	31	1	0	1	.11000000-01	9.00	.00	0	.00	.0
LINE	LN30	10	1	0	1	.11000000-01	12.00	1.50	4	2.00	30.0
PUMP	HP02	21	1	0	1	.00000000	.00	.00	0	.00	.0
LINE	LN31	10	1	0	1	.18000000-01	120.00	2.00	4	2.00	30.0
VALVE	SV02	21	1	0	1	.18000000-01	5.60	.00	0	.00	.0
LINE	LN32	10	1	0	1	.18000000-01	12.00	2.00	4	2.00	30.0
TAP	FT24	31	1	0	1	.18000000-01	5.60	.00	0	.00	.0
LINE	LN33	10	1	0	1	.18000000-01	24.00	2.00	4	2.00	30.0
TANK	TK02	0	1	0	2	.00000000	.00	.00	4	2.00	30.0
END		0	0	0	0	.00000000	.00	.00	0	.00	.0

NAME USERS NAME * * * * * PAGE 5
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:01:51
 BLD. 104 * AT4307 * CASF 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

***** D U T Y C Y C L E D A T A *****

OPER.TIME	NON-OPERATING	MIB-DEGRAD.	UNITS OPER.	HORSEPOWER	AMB.PRESSURE	POWER-KW	REPRES.TIME
.45800000+01	.54000000+03	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.61500000+01	.79750000+04	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.35800000+01	.20340000+04	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.3E800000+02	.53600000+03	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.74300000+01	.20610000+04	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.35800000+01	.59300000+03	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.66100000+02	.53600000+03	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.32300000+02	.71400000+03	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.10410000+03	.56200000+03	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.31900000+02	.18760000+04	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.16160000+02	.57104800+06	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.10000000+03	.95840000+04	.90000000+00	3	.00000000	.00000000	.00000000	.00000000
.00000000	-.10000000+01	.00000000	0	.00000000	.00000000	.00000000	.00000000

NAME USERS NAME ***** PAGE 6
DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
EXT. 30235 * * TIME 15:01:51
BLD. 104 * AT4307 * CASE 1

ACPS - TEST DEMONSTRATION PROBLEM

***** ENGINE DATA *****

3 NUMBER OF ENGINES
.35000000+03 GAS INLET TEMP.
.40000000+03 GAS INLET PRES.
.17500000+04 ENGINE THRUST
.25000000+03 CHAMBER PRES.
.40000000+02 EXPANSION RATIO
.40000000+01 MIXTURE RATIO

NAME USERS NAME * * * * * PAGE 7
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:01:51
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

***** T A N K D A T A *****

1	1	NUMBER OPERATING (NOP)
1	1	ACQUISITION TYPE
2	2	INSULATION TYPE
2	2	MATERIAL TYPE
2	2	PRESSURIZATION TYPE
.16500000+03	.37000000+02	INITIAL TEMPERATURE (R)
.16000000+02	.16000000+02	INITIAL PRESSURE
.17000000+03	.40000000+02	PRESSURANT GAS TEMP. (R)
.26700000+02	.19100000+02	OPERATING PRESS. (PSIA)
.31700000+02	.24100000+02	VENTING PRESSURE
.20000000+00	.30000000+00	HEAT FLUX (BTU/HR-FT**2)
.20000000+01	.20000000+01	INSULATION THICKNESS
.00000000	.00000000	INITIAL FLUID LOAD (OPT)
.30000000+01	.30000000+01	PERCENT ULLAGE VOLUME
.50660000+01	.50000000+01	MAXIMUM DIAMETER (FT)
.00000000	.00000000	HEX OUTLET TEMP. (R)
.00000000	.00000000	HEX DELTA PRESS. (PSIA)
.00000000	.00000000	PUMP DELTA PRESS. (PSIA)
.00000000	.00000000	GAS GEN OUTLET TEMP (R)
.00000000	.00000000	P SUD C OF GAS GEN (PSIA)
.00000000	.00000000	GAS GEN MIXTURE PATIO
.00000000	.00000000	NUMBER INSULATION LAYERS
1		TANK WEIGHT-CONFIGURATION OPTION CONSIDERED
0		NUMBER OF TANK SHAPES IN CONFIGURATION

NAME USERS NAME ***** PAGE 8
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:01:51
 BLD. 104 * AT4307 * CASE 1

 ACPS - TEST DEMONSTRATION PROBLEM

***** ACCUMULATOR DATA *****

1	1	NUMBER OPERATING (NOP)
4	4	INSULATION TYPE
1	1	MATERIAL TYPE
.35000000+03	.35000000+03	OPERATING TEMP. (DEG R)
.20000000+04	.20000000+04	OPERATING PRESS. (PSIA)
.10000000+00	.20000000+00	HEAT FLUX (BTU/HR-FT**2)
.20000000+01	.20000000+01	INSULATION THICKNESS
.25000000+01	.72500000+02	TANK VOLUME (CU. FT.)
.20500000+01	.52000000+01	MAXIMUM DIAMETER (FT)
.50000000+03	.50000000+03	NOMINAL OPER. DELTA PRES
.00000000	.00000000	NUMBER INSULATION LAYERS

NAME USERS NAME * * * * * PAGE 9
 DEFT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:01:51
 ELD. 104 * AT4307 * CASE 1
 * * * * *

ACPS - TEST DEMONSTRATION PROBLEM

***** HEAT EXCHANGER DATA *****

NUMBER OF HEAT EXCHANGERS INPUT = 1

- 1 -		- 2 -		- 3 -		- 4 -		- 5 -		HEAT EXCHANGER NUMBER
OXYGEN	HYDROGEN	OXYGEN	HYDROGEN	OXYGEN	HYDROGEN	OXYGEN	HYDROGEN	OXYGEN	HYDROGEN	
2000.0	2000.0	.0	.0	.0	.0	.0	.0	.0	.0	HEX HOT INLET TEMP.
1100.0	1028.0	.0	.0	.0	.0	.0	.0	.0	.0	HEX HOT OUTLET TEMP.
173.0	42.0	.0	.0	.0	.0	.0	.0	.0	.0	HEX COLD INLET TEMP.
350.0	350.0	.0	.0	.0	.0	.0	.0	.0	.0	HEX COLD OUTLET TEMP.
245.0	500.0	.0	.0	.0	.0	.0	.0	.0	.0	HEX HOT INLET PRES.
215.0	470.0	.0	.0	.0	.0	.0	.0	.0	.0	HEX HOT OUTLET PRES.
2030.0	2010.0	.0	.0	.0	.0	.0	.0	.0	.0	HEX COLD INLET PRES.
2000.0	2000.0	.0	.0	.0	.0	.0	.0	.0	.0	HEX COLD OUTLET PRES.
30.0	30.0	.0	.0	.0	.0	.0	.0	.0	.0	HEX HOT SIDE DELTA-P
30.0	10.0	.0	.0	.0	.0	.0	.0	.0	.0	HEX COLD SIDE DELTA-P
1.0	1.0	.0	.0	.0	.0	.0	.0	.0	.0	HEX GAS GEN. O/F RATIO

NAME USERS NAME * * * * * PAGE 10
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:01:51
 SLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

***** HIGH PRES PUMP DATA *****

2	2	TYPE
.52000000+00	.54000000+00	EFFICIENCY
.87000000+01	.11000000+01	NET + SUCTION HEAD
.20000000+05	.70000000+05	SHAFT SPEED
.20230000+04	.20230000+04	ESTIMATED DELTA PRES.

***** LOW PRES PUMP DATA *****

.00000000	.00000000	PUMP EFFICIENCY
.00000000	.00000000	NET POS. SUCTION HEAD
.00000000	.00000000	PUMP PRESSURE RISE
.00000000	.00000000	PUMP FLOW RATE

***** TURBINE DATA *****

.55000000+00	.36000000+00	TURBINE EFFICIENCY
.20000000+04	.20000000+04	TURBINE INLET TEMP.
.11600000+04	.11600000+04	TURBINE OUTLET TEMP.
.89100000+00	.89100000+00	TURBINE MIXTURE RATIO
.25000000+03	.50000000+03	TURBINE GAS GEN. PSURC

NAME USERS NAME * * * * * PAGE 11
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:01:52
 BLD. 104 * AT4307 * CASE 1
 * * * * *

ACPS - TEST DEMONSTRATION PROBLEM

***** H E A T S O U R C E D A T A *****

NUMBER OF HEAT SOURCES INPUT = 1

- 1 -		- 2 -		- 3 -		- 4 -		- 5 -		HEAT SOURCE NUMBER
OXYGEN	HYDROGEN	OXYGEN	HYDROGEN	OXYGEN	HYDROGEN	OXYGEN	HYDROGEN	OXYGEN	HYDROGEN	
1	1	0	0	0	0	0	0	0	0	HEAT SOURCE TYPE
1.0	1.0	.0	.0	.0	.0	.0	.0	.0	.0	HEAT SOURCE MIX. RATIO
2060.0	2060.0	.0	.0	.0	.0	.0	.0	.0	.0	HEAT SOURCE OUTLET TEMP.
.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	HEAT SOURCE AVAIL. ENERGY
245.0	500.0	.0	.0	.0	.0	.0	.0	.0	.0	HEAT SOURCE PRESSURE

NAME USERS NAME ***** PAGE 12
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:01:53
 ELD. 104 * AT4307 * CASE 1

 ACPS - TEST DEMONSTRATION PROBLEM

*** INITIATE PROGRAM AND CHARACTERIZE CONSUMER PARAMETERS ***

* COMPUTED ENGINE PARAMETERS *

ENGINE ISP	.46712069+03
ENGINE WEIGHT - (LBS)	.15937500+03
TOTAL ENGINE FLOW - (LB/SEC)	.12487850+02
ONE ENGINE OXID.FLOW RATE-(LB/SEC)	.99902804+01
ONE ENGINE FUEL FLOW RATE-(LB/SEC)	.24975701+01
THRUST IMPULSE PROPELLANT WGT.	.51784617+04

NAME USERS NAME * * * * * PAGE 13
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:01:53
 ELD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** COMPUTED FLOWRATE DATA ***

	OXIDYZER	FUEL
WDOT OX-TURB.-G.G.	.551258-01	.618696-01
WDOT HY-TURB.-G.G.	.370016+00	.415281+00
WDOT BOTH TURB.-GG	.425141+00	.477151+00
WDOT OXY HEX.-G.G.	.300310+00	.300310+00
WDOT HYD HEX.-G.G.	.132594+01	.132594+01
WDOT BOTH HEX.-G.G	.162626+01	.162626+01
TOTAL FLOWRATE **	.120417+02	.460098+01

NAME USERS NAME * * * * * PAGE 14
 DEPT 6213 * THE INTEGRATED HATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:01:53
 ELD. 104 * AT4307 * CASE 1
 * * * * *

ACPS - TEST DEMONSTRATION PROBLEM

*** SUMMARY OF COMPUTED SYSTEM CONFIGURATION PARAMETERS ***

F	CODE	FT	NO	NS	IS	IDX	G	GS	FCOEF	L/D	DIAM	ITHICK	PRES	TEMP	WDOT	WEIGHT	MACH	MFLAG
GAS	02-VAP	1	1	0	1	1	1	1	.000000	.0000	.0000	.0000	.00	.00	.00	.000	.0000000	
ENG	ENG1	0	3	0	1	2	1	1	.000000	.0000	.0000	.0000	400.00	350.00	9.99	159.375	.0000000	
LIN	LN01	0	3	0	1	3	1	1	.009500	110.0000	2.0000	.5000	400.35	350.00	9.99	4.009	.1307953	
TEE	FT01	1	1	0	1	4	1	1	.009500	126.3000	2.0000	.0000	407.49	350.00	9.99	.433	.1280855	
LIN	LN02	0	1	0	1	5	1	1	.009500	150.0000	2.0000	.5000	411.66	350.00	9.99	5.466	.1265442	
TAP	FT02	1	1	0	1	6	1	1	.009500	10.5000	2.0000	.0000	412.25	350.00	12.04	.342	.1522731	
VAL	LN03	0	1	0	1	7	1	1	.009500	24.0000	2.0000	.5000	413.21	350.00	12.04	.875	.1518509	
VAL	IV01	1	1	0	1	8	1	1	.009500	10.5000	2.0000	.0000	414.05	350.00	12.04	6.314	.1514840	
VAL	CV02	1	1	0	1	9	1	1	.009500	12.0000	2.0000	.5000	414.53	350.00	12.04	.437	.1512755	
VAL	CV02	1	1	0	1	10	1	1	.009500	135.0000	2.0000	.0000	425.15	350.00	12.04	4.406	.1467768	
VAL	LN05	0	1	0	1	11	1	1	.009500	40.0000	2.0000	.5000	426.70	350.00	12.04	1.458	.1461381	
TAP	FT03	1	1	0	1	12	1	1	.009500	10.5000	2.0000	.0000	427.51	350.00	12.04	.342	.1458060	
VAL	LN06	0	1	0	1	13	1	1	.009500	20.0000	2.0000	.5000	428.29	350.00	12.04	.729	.1454915	
REG	PR01	2	1	0	1	14	1	1	.009500	336.8000	2.0000	.0000	1750.00	350.00	12.04	9.630	.0000000	
VAL	LN07	0	1	0	1	15	1	1	.009500	30.0000	2.0000	.5000	1750.20	350.00	12.04	1.913	.0180427	
ACC	AC01	0	1	0	1	16	1	1	.000000	.0000	.0000	2.0000	2000.00	350.00	12.04	.000	.0000000	
VAL	LN08	0	1	0	1	17	1	1	.009500	24.0000	2.0000	.5000	2000.14	350.00	12.04	1.531	.0155240	
VAL	LN09	0	1	0	1	18	1	1	.000000	.0000	.0000	.0000	2022.29	173.00	12.04	22.655	.0000000	
GAS	02-LIG	1	2	0	1	19	1	2	.000000	.0000	.0000	.0000	2022.29	173.00	12.04	.000	.0000000	
VAL	LN09	0	1	0	1	20	1	2	.018000	12.0000	1.0000	.5000	2023.94	173.00	12.04	.383	.0000000	
VAL	CV01	1	1	0	1	21	1	2	.018000	.0000	1.0000	.0000	2023.94	173.00	12.04	9.000	.0000000	
VAL	LN10	0	1	0	1	22	1	2	.018000	12.0000	1.0000	.5000	2025.58	173.00	12.04	.383	.0000000	
VAL	LN13	0	1	0	1	28	1	2	.015000	24.0000	2.5000	.5000	15.97	165.00	12.04	1.093	.0000000	
TAP	FT04	1	1	0	1	27	1	2	.015000	6.6700	2.5000	.0000	15.95	165.00	12.04	.534	.0000000	
VAL	LN12	0	1	0	1	26	1	2	.015000	12.0000	2.5000	.5000	15.94	165.00	12.04	.547	.0000000	
VAL	SV01	1	1	0	1	25	1	2	.015000	6.6700	1.5000	.0000	15.79	165.00	12.04	4.142	.0000000	
VAL	LN11	0	1	0	1	24	1	2	.018000	160.0000	1.5000	.5000	12.98	165.00	12.04	4.373	.0000000	
PUR	HP01	1	1	0	1	23	1	2	.000000	.0000	.0000	.0000	12.98	165.00	12.04	73.362	.0000000	
TAN	TK01	0	1	0	1	29	1	2	.000000	.0000	.0000	2.0000	16.00	165.00	12.04	.000	.0000000	

NAME USERS NAME * * * * * PAGE 15
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:00
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** SUMMARY OF COMPUTED SYSTEM CONFIGURATION PARAMETERS - CONTD. ***

F	CODE	FT	NO	MS	IS	IDX	G	GS	FCOEF	L/D	DIAM	ITICK	PRES	TEMP	WDOT	WEIGHT	MACH	MFLAG
GAS	H2-VAP	2	1	0	1	30	2	1	.000000	.0000	.0000	.0000	.00	.00	.00	.000	.00000000	
ENG	ENG1	0	3	0	1	31	2	1	.000000	.0000	.0000	.0000	400.00	350.00	2.50	159.375	.00000000	
LIN	LN21	0	3	0	1	32	2	1	.011000	110.0000	1.7500	2.0000	400.12	350.00	2.50	3.508	.2095926	
TEE	FT21	1	1	0	1	33	2	1	.011000	109.0000	1.7500	.0000	401.92	350.00	2.50	.331	.2086492	
LIN	LN22	0	1	0	1	34	2	1	.011000	150.0000	1.7500	2.0000	403.33	350.00	2.50	4.783	.2079167	
TAP	FT22	1	1	0	1	35	2	1	.011000	9.0000	1.7500	.0000	403.48	350.00	4.60	.262	.3828795	*
LIN	LN23	0	1	0	1	36	2	1	.011000	24.0000	1.7500	2.0000	404.24	350.00	4.60	.765	.3821540	*
VAL	IV02	1	1	0	1	37	2	1	.011000	9.0000	1.7500	.0000	404.74	350.00	4.60	6.121	.3816802	*
LIN	LN24	0	1	0	1	38	2	1	.011000	12.0000	1.7500	2.0000	405.12	350.00	4.60	.383	.3813205	*
VAL	CV04	1	1	0	1	39	2	1	.011000	86.0000	1.7500	.0000	409.86	350.00	4.60	4.255	.3768958	*
LIN	LN25	0	1	0	1	40	2	1	.011000	40.0000	1.7500	2.0000	411.11	350.00	4.60	1.275	.3757436	*
TAP	FT23	1	1	0	1	41	2	1	.011000	9.0000	1.7500	.0000	411.60	350.00	4.60	.262	.3752932	*
LIN	LN26	0	1	0	1	42	2	1	.011000	20.0000	1.7500	2.0000	412.22	350.00	4.60	.638	.3747235	*
REG	PR02	2	1	0	1	43	2	1	.011000	336.4000	1.7500	.0000	1750.00	350.00	4.60	9.392	.00000000	
LIN	LN27	0	1	0	1	44	2	1	.011000	30.0000	1.7500	2.0000	1750.24	350.00	4.60	1.674	.0938032	
ACC	AC02	0	1	0	1	45	2	1	.000000	.0000	.0000	2.0000	2000.00	350.00	4.60	.000	.00000000	
LIN	LN28	0	1	0	1	46	2	1	.011000	24.0000	1.5000	2.0000	2000.36	350.00	4.60	1.148	.1132123	
HEX	HX03	1	1	0	1	47	2	1	.000000	.0000	.0000	.0000	2010.19	42.00	4.60	61.123	.00000000	
GAS	H2-LI ^a	2	2	0	1	48	2	2	.000000	.0000	.0000	.0000	2010.19	42.00	4.60	.000	.00000000	
LIN	LN29	0	1	0	1	49	2	2	.011000	12.0000	1.5000	2.0000	2010.23	42.00	4.60	.574	.00000000	
VAL	CV03	1	1	0	1	50	2	2	.011000	9.0000	1.5000	.0000	2010.28	42.00	4.60	9.214	.00000000	
LIN	LN30	0	1	0	1	51	2	2	.011000	12.0000	1.5000	2.0000	2010.32	42.00	4.60	.574	.00000000	
LIN	LN33	0	1	0	1	57	2	2	.018000	24.0000	2.0000	2.0000	15.97	37.00	4.60	.875	.00000000	
TAP	FT24	1	1	0	1	56	2	2	.018000	5.6000	2.0000	.0000	15.96	37.00	4.60	.342	.00000000	
LIN	LN32	0	1	0	1	55	2	2	.018000	12.0000	2.0000	2.0000	15.94	37.00	4.60	.437	.00000000	
VAL	SV02	1	1	0	1	54	2	2	.018000	5.6000	2.0000	.0000	15.93	37.00	4.60	4.406	.00000000	
LIN	LN31	0	1	0	1	53	2	2	.018000	120.0000	2.0000	2.0000	15.77	37.00	4.60	4.373	.00000000	
PUR	HP02	1	1	0	1	52	2	2	.000000	.0000	.0000	.0000	15.77	37.00	4.60	34.569	.00000000	
TAN	TK02	0	1	0	1	58	2	2	.000000	.0000	.0000	2.0000	16.00	37.00	4.60	.000	.00000000	

NAME USERS NAME ***** PAGE 16
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:01
 BLD. 104 * AT4307 * CASE 1

 ACPS - TEST DEMONSTRATION PROBLEM

*** SUMMARY OF COMPUTED HEAT EXCHANGER CHARACTERISTICS ***

	FOR UNITS	HX01	HX03
HEAT EXCHANGER CHARACTERISTICS	OXYGEN	HYDROGEN	
COLD FLUID INLET TEMP	.173000+03	.420000+02	
COLD FLUID OUTLET TEMP	.350000+03	.350000+03	
COLD FLUID SPECIFIC HEAT	.485697+00	.373836+01	
COLD FLUID FLOW RATE	.120417+02	.460098+01	
HOT FLUID INLET TEMP	.200000+04	.200000+04	
HOT FLUID OUTLET TEMP	.110000+04	.102800+04	
HOT FLUID SPECIFIC HEAT	.185245+01	.184709+01	
HOT FLUID FLOW RATE	.620922+00	.295072+01	
COLD SIDE EFFECTIVENESS	.968801-01	.157303+00	
HOT SIDE EFFECTIVENESS	.492611+00	.496425+00	
TOTAL EFFECTIVENESS	.589491+00	.653728+00	
HX SUBUNIT TYPE ***	SUP-CRITICAL	SUP-CRITICAL	
THERML CONDUCTANCE RATIO	.784822+00	.551711+00	
HOT FLUID FLOW RATE	.323065+00	.101027+00	
COLD FLUID DELTA - P	.780449+01	.171191+00	
CAPACITY RATIO	.116889+00	.179012-01	
NUMBER OF TRANSFER UNITS	.715320+00	.691449+00	
COMPUTED VALUE OF UA	.154113+04	.464504+03	
COMPUTED VALUE OF W/UA	.587501-02	.649877-02	
HEIGHT OF SUBUNIT	.137806+02	.418989+01	
HX SUBUNIT TYPE ***	PARALLEL-FLO	PARALLEL-FLO	
THERML CONDUCTANCE RATIO	.790265+00	.140564+01	
HOT FLUID FLOW RATE	.297075+00	.284969+01	
COLD FLUID DELTA - P	.143533+02	.965759+01	
CAPACITY RATIO	.797778-01	.298971+00	
NUMBER OF TRANSFER UNITS	.769651+00	.809568+00	
COMPUTED VALUE OF UA	.152479+04	.153405+05	
COMPUTED VALUE OF W/UA	.582023-02	.371129-02	
HEIGHT OF SUBUNIT	.887461+01	.569331+02	
HEIGHT OF HEAT EXCHANGER	.226552+02	.611230+02	

NAME USERS NAME * * * * * PAGE 17
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:01
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** SUMMARY OF COMPUTED HEAT EXCHANGER-GAS GENERATOR CHARACTERISTICS ***

GAS GENERATOR CHARACTERISTICS	OXYGEN	HYDROGEN
GAS GEN. FLOW RATE - (LB/SEC)	.620922+00	.295072+01
GAS GEN. PROPELLANT WGT.-(LBS)	.257484+03	.122361+04
GAS GENERATOR WEIGHT - (LBS)	.136186+02	.161016+02
WEIGHT OF HEX-GAS GEN. ASSY.	.362738+02	.772246+02
CUMULATIVE GAS GEN. PROP. WGT.	.257484+03	.122361+04
CUMULATIVE HEAT REQD. - (BTU)	.000000	.000000
CUMULATIVE HOT FLUID - (LBS)	.000000	.000000

NAME USERS NAME * * * * * PAGE 18
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:02
 BLD. 104 * AT4307 * CASE 1
 * * * * * ACPS - TEST DEMONSTRATION PROBLEM * * * * *

*** SUMMARY OF COMPUTED PUMP CHARACTERISTICS FOR THE SYSTEM ***

PUMP CHARACTERISTICS	OXYGEN	HYDROGEN
TEMPERATURE	.165000+03	.370000+02
PRESSURE	.129757+02	.157742+02
FLOW RATE	.120417+02	.460098+01
DELTA-PRESSURE	.201261+04	.199454+04
PSH AVAILABLE	.870000+01	.110000+01
DENSITY OF FLUID	.708162+02	.443309+01
NUMBER OF STAGES REQD.	1	5
COMPUTED NFSP REQD	.218270+01	.336251+00
COMPUTED PUMP EFF.	.725520+00	.766746+00
COMPUTED PUMP VOL.	.490617+02	.133186+03
COMPUTED PUMP WGT.	.146742+01	.359000+01
COMPUTED PUMP PWR.	.123499+03	.706864+03
COMPUTED PUMP SPD.	.174980+05	.834961+05
SELECTED PUMP OPTION	2	2

*** SUMMARY OF COMPUTED TURBINE CHARACTERISTICS FOR THE SYSTEM ***

TURBINE CHARACTERISTICS	OXYGEN	HYDROGEN
TURBINE ROTOR MEAN DIAMETER	.850669+01	.274264+01
WGT. OF PWR. TRANSMISSION ASSY	.137516+02	.103401+02
WGT. OF TURBINE ROTOR	.696344+01	.233372+00
WGT. OF MANIFOLD AND NOZZLE	.339364+02	.140023+01
HEIGHT OF INDUCER	.500000+01	.500000+01
HEIGHT OF TURBINE ASSY.	.596515+02	.186073+02

*** SUMMARY OF COMPUTED TURBINE GAS GENERATOR CHARACTERISTICS ***

GAS GENERATOR CHARACTERISTICS	OXYGEN	HYDROGEN
GAS GEN. FLOW RATE - (LB/SEC)	.879073-01	.554576+00
GAS GEN. PROPELLANT WGT.-(LRS)	.364534+02	.229972+03
GAS GENERATOR HEIGHT - (LRS)	.122426+02	.123712+02

NAME USERS NAME * * * * * PAGE 19
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * TIME 15:02:03
 SLD. 104 * CASE 1
 * * * * * AT4307 * * * * *
 * * * * * ACPS - TEST DEMONSTRATION PROBLEM * * * * *

*** INITIAL TANK SIZING CALCULATIONS ***

	OXYGEN	HYDROGEN
NUMBER OF TANKS	1	1
MATERIAL TYPE	2	2
FLUID WGT. (TOTAL)	.510113+04	.194820+04
FLUID VOLUME /TANK	.720333+02	.439468+03
WGT ADDED CYL SECT	.306852+00	.197408+02
DIAMETER (FT)/TANK	.506600+01	.500000+01
SURFACE AREA /TANK	.855106+02	.388627+03
TANK VOLUME / TANK	.742612+02	.453059+03
TANK WGT. (LB) TOT	.426906+02	.192650+03
HEAT LEAK BTU/H/FT	.475059-02	.323856-01

NAME USERS NAME * * * * * PAGE 20
 DEPT 4213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:03
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 APCS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS ***

*** INITIAL TANK CONDITIONS ***

FLUID CONSIDERED -	OXYGEN	FLUID TEMPERATURE	=	163.91	TANK INITIAL PRESSURE =	16.00
WGT.OF LIQ. PROP.	= 5101.13	WGT. PROP. VAPOR	=	.741	WGT. LIQ. + VAPOR	= 5101.87
PCT. HELIUM IN VAPOR	= .00	TOTAL FLUIDS IN TANK	=	5101.87	VOL. OF LIQUID FLUID	= 71.80
PART.PRES.PROP.VAPOR	= 16.000	PART.PRES.HELIIUM GAS	=	.000	ULLAGE VOLUME IN TANK	= 2.46
TANK VOLUME	= 74.26	EFF. TANK DENSITY	=	66.702	EFF. INTERNAL ENERGY	= -.56810388+02

***** COAST NUMBER = 1 PRESS.SYS.NO. = 0 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	OXYGEN	FLUID TEMPERATURE	=	163.99	COAST DURATION - SEC. =	540.
WGT.OF LIQ. PROP.	= 5101.125	WGT. PROP. VAPOR	=	.744	WGT.HELIIUM IN VAPOR	= .000
PART.PRES.PROP.VAPOR	= 16.074	PART.PRES.HELIIUM GAS	=	.000	CURRENT TANK PRESSURE =	16.074
EFF.INTERNAL ENERGY	= -.56809686+02					

***** BURN NUMBER = 1 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	OXYGEN	BURN DURATION - SEC.	=	5.	FLOWRATE FOR THRUST	= 9.990
THRUST PROP.REMAINING	= 4235.05	PROPELLANT IN TANK	=	5101.13	EFF. INTERNAL ENERGY	= -.56809886+02
EFF. TANK ENERGY	= -.28672176+06				TOTAL FLOWRATE	= 12.033

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 55.113	TOTAL FLUIDS IN TANK	=	5046.76	PROPELLANT LIQ.+VAP.	= 5046.76
THRUST PROP.REMAINING	= 4189.29	NEW EFF. TANK DENSITY	=	67.9596	PART.PRES.PROP.VAPOR	= 16.056
NEW INTERNAL ENERGY	= -.56813077+02					

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 163.97	STORED HELIUM TEMP.	=	170.00	NEW TANK ULLAGE VOL.	= 3.230
NEW PROP. LIQ. VOLUME	= 71.03	PROP. LIQ. REMAINING	=	5045.78	WGT. OF PROP. VAPOR	= .9742
HELIUM PART.PRESSURE	= 10.644	TOTAL PRES. *FPV+PHE*	=	16.056	NOM. OPERATING PRES.	= 26.700
HELIUM FLOW RATE	= .1644-01	WEIGHT OF HELIUM USED	=	.7528-01	NEW TANK PRESSURE	= 26.700
TOTAL HELIUM CONSUMED	= .075					

NAME USERS NAME * * * * * PAGE 21
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:03
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACP5 - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 2 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	OXYGEN	FLUID TEMPERATURE	=	164.00	COAST DURATION - SEC. =	7975.
WGT.OF LIQ. PROP.	= 5045.781	WGT. PROP. VAPOR	=	.976	WGT. HELIUM IN VAPOR =	.075
PART.PRES.PROP.VAPOR	= 16.084	PART.PRES. HELIUM GAS	=	10.269	CURRENT TANK PRESSURE =	26.353
EFF. INTERNAL ENERGY	= -.56805571+02					

***** BURN NUMBER = 2 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	OXYGEN	BURN DURATION - SEC. =	6.	FLOWRATE FOR THRUST =	9.990
THRUST PROP. REMAINING	= 4189.29	PROPELLANT IN TANK =	5046.76	EFF. INTERNAL ENERGY =	-.56805571+02
EFF. TANK ENERGY	= -.28250102+06			TOTAL FLOWRATE =	12.035

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 74.016	TOTAL FLUIDS IN TANK =	4972.74	PROPELLANT LIQ.+VAP. =	4972.74
THRUST PROP. REMAINING	= 4127.85	NEW EFF. TANK DENSITY =	66.9629	PART.PRES.PROP.VAPOR =	16.061
NEW INTERNAL ENERGY	= -.56809925+02				

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =	163.97	STORED HELIUM TEMP. =	170.00	NEW TANK ULLAGE VOL. =	4.275
NEW PROP. LIQ. VOLUME =	69.99	PROP. LIQ. REMAINING =	4971.45	WGT. OF PROP. VAPOR =	1.2898
HELIUM PART.PRESSURE =	10.639	TOTAL PRES. *FPV+PHE* =	23.817	NON. OPERATING PRES. =	26.700
HELIUM FLOW RATE =	.3955-02	WEIGHT OF HELIUM USED =	.2432-01	NEW TANK PRESSURE =	26.700
TOTAL HELIUM CONSUMED =	.100				

NAME USERS NAME * * * * * PAGE 22
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:03
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTO. ***

***** COAST NUMBER = 3 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	OXYGEN	FLUID TEMPERATURE	=	163.98	COAST DURATION - SEC. =	2094.
WGT.OF LIQ. PROP.	= 4971.450	WGT. PROP. VAPOR	=	1.290	WGT.HELUM IN VAPOR =	.100
PART.PRES.PROP.VAPOR	= 16.069	PART.PRES.HELUM GAS	=	10.263	CURRENT TANK PRESSURE =	26.332
EFF.INTERNAL ENERGY	= -.56807924+02					

***** BURN NUMBER = 3 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	OXYGEN	BURN DURATION - SEC. =	4.	FLOWRATE FOR THRUST =	9.990
THRUST PROP.REMAINING =	4127.85	PROPELLANT IN TANK =	4972.74	EFF. INTERNAL ENERGY =	-.56807924+02
EFF. TANK ENERGY =	-.28005587+06			TOTAL FLOWRATE =	12.035

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN =	43.086	TOTAL FLUIDS IN TANK =	4929.65	PROPELLANT LIQ.+VAP. =	4929.65
THRUST PROP.REMAINING =	4092.09	NEW EFF. TANK DENSITY =	66.3827	PART.PRES.PROP.VAPOR =	16.055
NEW INTERNAL ENERGY =	-.56810441+02				

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =	163.97	STORED HELIUM TEMP. =	170.00	NEW TANK ULLAGE VOL. =	4.886
NEW PROP. LIQ. VOLUME =	69.38	PROP. LIQ. REMAINING =	4928.18	WGT. OF PROP. VAPOR =	1.4735
HELIUM PART.PRESSURE =	10.645	TOTAL PRES. *PPV+PHE* =	25.035	NOM. OPERATING PRES. =	26.700
HELIUM FLOW RATE =	.3990-02	WEIGHT OF HELIUM USED =	.1426-01	NEW TANK PRESSURE =	26.700
TOTAL HELIUM CONSUMED =	.114				

LOCKHEED MISSILES & SPACE COMPANY

176

LMSC-A991396

NAME USERS NAME * * * * * PAGE 23
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:04
 BLD. 104 * AT4307 * CASE 1
 * * * * * ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 4 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	OXYGEN	FLUID TEMPERATURE	=	163.97	COAST DURATION - SEC.	=	536.
WGT.OF LIQ. PROP.	= 4928.181	WGT. PROP. VAPOR	=	1.474	WGT. HELIUM IN VAPOR	=	.114
PART.PRES.PROP.VAPOR	= 16.056	PART.PRES. HELIUM GAS	=	10.268	CURRENT TANK PRESSURE	=	26.326
EFF. INTERNAL ENERGY	= -.56809925+02						

***** BURN NUMBER = 4 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	OXYGEN	BURN DURATION - SEC.	=	39.	FLOWRATE FOR THRUST	=	9.990
THRUST PROP.REMAINING	= 4092.09	PROPELLANT IN TANK	=	4929.65	EFF. INTERNAL ENERGY	=	-.56809925+02
EFF. TANK ENERGY	= -.25365855+06				TOTAL FLOWRATE	=	12.035

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 466.961	TOTAL FLUIDS IN TANK	=	4462.69	PROPELLANT LIQ.+VAP.	=	4462.69
THRUST PROP.REMAINING	= 3704.47	NEW EFF. TANK DENSITY	=	60.0946	PART.PRES.PROP.VAPOR	=	15.918
NEW INTERNAL ENERGY	= -.56839786+02						

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 163.82	STORED HELIUM TEMP.	=	170.00	NEW TANK ULLAGE VOL.	=	11.516
NEW PROP. LIQ. VOLUME	= 62.75	PROP. LIQ. REMAINING	=	4459.25	WGT. OF PROP. VAPOR	=	3.4458
HELIUM PART.PRESSURE	= 10.782	TOTAL PRES. *PPV+PHE*	=	20.270	NOM. OPERATING PRES.	=	26.700
HELIUM FLOW RATE	= .4072-02	WEIGHT OF HELIUM USED	=	.1580+00	NEW TANK PRESSURE	=	26.700
TOTAL HELIUM CONSUMED	= .272						

NAME USERS NAME * * * * * PAGE 24
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * TIME 15102104
 BLD. 104 * CASE 1
 * * * * * AT4307 * * * * *
 * * * * * ACPS - TEST DEMONSTRATION PROBLEM * * * * *

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 5 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	OXYGEN	FLUID TEMPERATURE	=	163.84	COAST DURATION - SEC. =	2061.
WGT. OF LIQ. PROP.	= 4459.244	WGT. PROP. VAPOR	=	3.450	WGT. HELIUM IN VAPOR =	.272
PART. PRES. PROP. VAPOR	= 15.939	PART. PRES. HELIUM GAS	=	10.392	CURRENT TANK PRESSURE =	26.332
EFF. INTERNAL ENERGY	= -.56837592+02					

***** BURN NUMBER = 5 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	OXYGEN	BURN DURATION - SEC. =	7.	FLOWRATE FOR THRUST =	9.990
THRUST PROP. REMAINING	= 3704.47	PROPELLANT IN TANK =	4462.69	EFF. INTERNAL ENERGY =	-.56837592+02
EFF. TANK ENERGY	= -.24858964+06			TOTAL FLOWRATE =	12.035

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 89.421	TOTAL FLUIDS IN TANK =	4373.27	PROPELLANT LIQ. + VAP. =	4373.27
THRUST PROP. REMAINING	= 3630.24	NEW EFF. TANK DENSITY =	59.8904	PART. PRES. PROP. VAPOR =	15.912
NEW INTERNAL ENERGY	= -.56842927+02				

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 163.81	STORED HELIUM TEMP. =	170.00	NEW TANK ULLAGE VOL. =	12.780
NEW PROP. LIQ. VOLUME	= 61.48	PROP. LIQ. REMAINING =	4369.45	WGT. OF PROP. VAPOR =	3.8229
HELIUM PART. PRESSURE	= 10.788	TOTAL PRES. *PPV+PHE* =	25.273	NOM. OPERATING PRES. =	26.700
HELIUM FLOW RATE	= .4042-02	WEIGHT OF HELIUM USED =	.3003-01	NEW TANK PRESSURE =	26.700
TOTAL HELIUM CONSUMED =	.302				

NAME USERS NAME * * * * * PAGE 25
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:04
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 APCS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 6 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	OXYGEN	FLUID TEMPERATURE	=	163.81	COAST DURATION - SEC.	=	593.
WGT.OF LIQ. PROP.	= 4369.449	WGT. PROP. VAPOR	=	3.824	WGT. HELIUM IN VAPOR	=	.302
PART.PRES.PROP.VAPOR	= 15.916	PART.PRES. HELIUM GAS	=	10.396	CURRENT TANK PRESSURE	=	26.313
EFF. INTERNAL ENERGY	= -.56842283+02						

***** BURN NUMBER = 6 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	OXYGEN	BURN DURATION - SEC.	=	4.	FLOWRATE FOR THRUST	=	9.990
THRUST PROP. REMAINING	= 3630.24	PROPELLANT IN TANK	=	4373.27	EFF. INTERNAL ENERGY	=	-.56842283+02
EFF. TANK ENERGY	= -.24614875+06				TOTAL FLOWRATE	=	12.035

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 43.086	TOTAL FLUIDS IN TANK	=	4330.19	PROPELLANT LIQ.+VAP.	=	4330.19
THRUST PROP. REMAINING	= 3594.47	NEW EFF. TANK DENSITY	=	58.3103	PART.PRES.PROP.VAPOR	=	15.903
NEW INTERNAL ENERGY	= -.56844824+02						

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 163.80	STORED HELIUM TEMP.	=	170.00	NEW TANK ULLAGE VOL.	=	13.391
NEW PROP. LIQ. VOLUME	= 60.87	PROP. LIQ. REMAINING	=	4326.18	WGT. OF PROP. VAPOR	=	4.0035
HELIUM PART.PRESSURE	= 10.797	TOTAL PRES. *PPV+PHE*	=	25.824	NOM. OPERATING PRES.	=	26.700
HELIUM FLOW RATE	= .4101-02	WEIGHT OF HELIUM USED	=	.1468-01	NEW TANK PRESSURE	=	26.700
TOTAL HELIUM CONSUMED	= .317						

179

LOCKHEED MISSILES & SPACE COMPANY

LMSC-A991396

NAME USERS NAME * * * * * PAGE 26
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:04
 BLD. 104 * AT4307 * CASE 1
 * * * * * ACPS - TEST DEMONSTRATION PROBLEM * * * * *

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 7 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	OXYGEN	FLUID TEMPERATURE	=	163.80	COAST DURATION - SEC. =	536.
WGT. OF LIQ. PROP.	= 4326.183	WGT. PROP. VAPOR	=	4.004	WGT. HELIUM IN VAPOR =	.317
PART. PRES. PROP. VAPOR	= 15.906	PART. PRES. HELIUM GAS	=	10.404	CURRENT TANK PRESSURE =	26.310
EFF. INTERNAL ENERGY	= -.56844236+02					

***** BURN NUMBER = 7 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	OXYGEN	BURN DURATION - SEC. =	66.	FLOWRATE FOR THRUST =	9.990
THRUST PROP. REMAINING	= 3594.47	PROPELLANT IN TANK =	4330.19	EFF. INTERNAL ENERGY =	-.56844236+02
EFF. TANK ENERGY	= -.20112651+06			TOTAL FLOWRATE =	12.035

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 795.519	TOTAL FLUIDS IN TANK =	3534.67	PROPELLANT LIQ. + VAP. =	3534.67
THRUST PROP. REMAINING	= 2734.12	NEW EFF. TANK DENSITY =	47.5978	PART. PRES. PROP. VAPOR =	15.752
NEW INTERNAL ENERGY	= -.56901096+02				

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =	163.63	STORED HELIUM TEMP. =	170.00	NEW TANK ULLAGE VOL. =	24.656
NEW PROP. LIQ. VOLUME =	49.61	PROP. LIQ. REMAINING =	3527.36	WGT. OF PROP. VAPOR =	7.3072
HELIUM PART. PRESSURE =	10.946	TOTAL PRES. *PPV+PHE* =	21.396	NOM. OPERATING PRES. =	26.700
HELIUM FLOW RATE =	.4152-02	WEIGHT OF HELIUM USED =	.2744+00	NEW TANK PRESSURE =	26.700
TOTAL HELIUM CONSUMED =	.591				

NAME USERS NAME * * * * * PAGE 27
 DEFT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:05
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 8 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	OXYGEN	FLUID TEMPERATURE	=	163.68	COAST DURATION - SEC. =	714.
WGT.OF LIQ. PROP.	= 3527.344	WGT. PROP. VAPOR	=	7.325	WGT. HELIUM IN VAPOR =	.591
PART.PRES.PROP.VAPOR	= 15.793	PART.PRES. HELIUM GAS	=	10.541	CURRENT TANK PRESSURE =	26.334
EFF. INTERNAL ENERGY	= -.56900137+02					

***** BURN NUMBER = 8 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	OXYGEN	BURN DURATION - SEC. =	32.	FLOWRATE FOR THRUST =	9.990
THRUST PROP. REMAINING	= 2934.12	PROPELLANT IN TANK =	3534.67	EFF. INTERNAL ENERGY =	-.56900137+02
EFF. TANK ENERGY	= -.17910453+06			TOTAL FLOWRATE =	12.035

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 388.733	TOTAL FLUIDS IN TANK =	3145.94	PROPELLANT LIQ.+VAP. =	3145.94
THRUST PROP. REMAINING	= 2611.43	NEW EFF. TANK DENSITY =	42.3631	PART.PRES.PROP.VAPOR =	15.902
NEW INTERNAL ENERGY	= -.56932047+02				

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =	163.80	STORED HELIUM TEMP. =	170.00	NEW TANK ULLAGE VOL. =	30.124
NEW PROP. LIQ. VOLUME =	44.14	PROP. LIQ. REMAINING =	3136.93	WGT. OF PROP. VAPOR =	9.0060
HELIUM PART.PRESSURE =	10.798	TOTAL PRES. *PPV+PHE* =	24.536	NOM. OPERATING PRES. =	26.700
HELIUM FLOW RATE =	.3752-02	WEIGHT OF HELIUM USED =	.1212+00	NEW TANK PRESSURE =	26.700
TOTAL HELIUM CONSUMED =	.712				

NAME USERS NAME * * * * * PAGE 28
 DEPT 6213 * THE INTEGRATED NATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:05
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 APCS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 9 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	OXYGEN	FLUID TEMPERATURE	=	163.82	COAST DURATION - SEC.	=	568.
WGT. OF LIQ. PROP.	= 3136.918	WGT. PROP. VAPOR	=	9.017	WGT. HELIUM IN VAPOR	=	.712
PART. PRES. PROP. VAPOR	= 15.924	PART. PRES. HELIUM GAS	=	10.406	CURRENT TANK PRESSURE	=	26.330
EFF. INTERNAL ENERGY	= -.56931190+02						

***** BURN NUMBER = 9 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	OXYGEN	BURN DURATION - SEC.	=	104.	FLOWRATE FOR THRUST	=	9.990
THRUST PROP. REMAINING	= 2611.43	PROPELLANT IN TANK	=	3145.94	EFF. INTERNAL ENERGY	=	-.56931190+02
EFF. TANK ENERGY	= -.10821124+06				TOTAL FLOWRATE	=	12.035

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 1252.852	TOTAL FLUIDS IN TANK	=	1893.08	PROPELLANT LIQ. + VAP.	=	1893.08
THRUST PROP. REMAINING	= 1571.44	NEW EFF. TANK DENSITY	=	25.4922	PART. PRES. PROP. VAPOR	=	14.508
NEW INTERNAL ENERGY	= -.57161386+02						

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 162.19	STORED HELIUM TEMP.	=	170.00	NEW TANK ULLAGE VOL.	=	47.937
NEW PROP. LIQ. VOLUME	= 26.32	PROP. LIQ. REMAINING	=	1879.91	WGT. OF PROP. VAPOR	=	13.1757
HELIUM PART. PRESSURE	= 12.192	TOTAL PRES. *PPV+PHE*	=	20.982	NOM. OPERATING PRES.	=	26.700
HELIUM FLOW RATE	= .5449-02	WEIGHT OF HELIUM USED	=	.5673+00	NEW TANK PRESSURE	=	26.700
TOTAL HELIUM CONSUMED	= 1.280						

NAME USERS NAME * * * * * PAGE 29
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:05
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 10 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	OXYGEN	FLUID TEMPERATURE	=	162.38	COAST DURATION - SEC. =	1876.
WGT.OF LIQ. PROP.	= 1879.780	WGT. PROP. VAPOR	=	13.302	WGT. HELIUM IN VAPOR =	1.280
PART.PRES.PROP.VAPOR	= 14.660	PART.PRES. HELIUM GAS	=	11.646	CURRENT TANK PRESSURE =	26.306
EFF. INTERNAL ENERGY	= -.57156679+02					

***** BURN NUMBER = 10 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	OXYGEN	BURN DURATION - SEC. =	32.	FLOWRATE FOR THRUST =	9.990
THRUST PROP. REMAINING	= 1571.44	PROPELLANT IN TANK =	1893.08	EFF. INTERNAL ENERGY =	-.57156679+02
EFF. TANK ENERGY	= -.86250527+05			TOTAL FLOWRATE =	12.035

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 383.919	TOTAL FLUIDS IN TANK =	1509.16	PROPELLANT LIQ.+VAP. =	1509.16
THRUST PROP. REMAINING	= 1252.75	NEW EFF. TANK DENSITY =	20.3224	PART.PRES.PROP.VAPOR =	14.350
NEW INTERNAL ENERGY	= -.57151208+02				

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =	162.00	STORED HELIUM TEMP. =	170.00	NEW TANK ULLAGE VOL. =	53.344
NEW PROP. LIQ. VOLUME =	20.92	PROP. LIQ. REMAINING =	1494.65	WGT. OF PROP. VAPOR =	14.5152
HELIUM PART. PRESSURE =	12.350	TOTAL PRES. *PPV+PHE* =	24.791	NOM. OPERATING PRES. =	26.700
HELIUM FLOW RATE =	.5102+02	WEIGHT OF HELIUM USED =	.1628+00	NEW TANK PRESSURE =	26.700
TOTAL HELIUM CONSUMED =	1.442				

NAME USERS NAME * * * * * PAGE 30
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * TIME 15:02:06
 BLD. 104 * AT4307 * CASE 1
 * * * * * ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 11 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	OXYGEN	FLUID TEMPERATURE	=	165.93	COAST DURATION - SEC.	=	571048.
WGT.OF LIQ. PROP.	= 1491.376	WGT. PROP. VAPOR	=	17.788	WGT. HELIUM IN VAPOR	=	1.442
PART. PRES. PROP. VAPOR	= 17.914	PART. PRES. HELIUM GAS	=	12.055	CURRENT TANK PRESSURE	=	29.969
EFF. INTERNAL ENERGY	= -.55353647+02						

***** BURN NUMBER = 11 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	OXYGEN	BURN DURATION - SEC.	=	16.	FLOWRATE FOR THRUST	=	9.990
THRUST PROP. REMAINING	= 1252.75	PROPELLANT IN TANK	=	1509.16	EFF. INTERNAL ENERGY	=	-.55353647+02
EFF. TANK ENERGY	= -.72687199+05				TOTAL FLOWRATE	=	12.035

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 194.487	TOTAL FLUIDS IN TANK	=	1314.68	PROPELLANT LIQ.+VAP.	=	1314.68
THRUST PROP. REMAINING	= 1091.31	NEW EFF. TANK DENSITY	=	17.7034	PART. PRES. PROP. VAPOR	=	16.731
NEW INTERNAL ENERGY	= -.55289029+02						

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 161.70	STORED HELIUM TEMP.	=	170.00	NEW TANK ILLAGE VOL.	=	55.961
NEW PROP. LIQ. VOLUME	= 18.30	PROP. LIQ. REMAINING	=	1297.15	WGT. OF PROP. VAPOR	=	17.5271
HELIUM PART. PRESSURE	= 11.406	TOTAL PRES. *PPV+PHE*	=	28.137	NOM. OPERATING PRES.	=	26.700
HELIUM FLOW RATE	= .0000	WEIGHT OF HELIUM USED	=	.0000	NEW TANK PRESSURE	=	28.137
TOTAL HELIUM CONSUMED	= 1.442						

NAME USERS NAME * * * * * PAGE 31
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:06
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 APCS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 12 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	OXYGEN	FLUID TEMPERATURE	=	164.77	COAST DURATION - SEC.	=	9584.
WGT.OF LIQ. PROP.	= 1297.085	WGT. PROP. VAPOR	=	17.592	WGT. HELIUM IN VAPOR	=	1.442
PART.PRES.PROP.VAPOR	= 16.798	PART.PRES. HELIUM GAS	=	11.410	CURRENT TANK PRESSURE	=	28.208
EFF. INTERNAL ENERGY	= -.55254397+02						

***** BURN NUMBER = 12 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	OXYGEN	BURN DURATION - SEC.	=	100.	FLOWRATE FOR THRUST	=	9.990
THRUST PROP. REMAINING	= 1091.31	PROPELLANT IN TANK	=	1314.68	EFF. INTERNAL ENERGY	=	-.55254397+02
EFF. TANK ENERGY	= -.49881426+04				TOTAL FLOWRATE	=	12.035

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 1203.508	TOTAL FLUIDS IN TANK	=	111.17	PROPELLANT LIQ.+VAP.	=	111.17
THRUST PROP. REMAINING	= 92.28	NEW EFF. TANK DENSITY	=	1.4970	PART.PRES.PROP.VAPOR	=	14.580
NEW INTERNAL ENERGY	= -.44870217+02						

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 162.28	STORED HELIUM TEMP.	=	170.00	NEW TANK ULLAGE VOL.	=	72.986
NEW PROP. LIQ. VOLUME	= 1.27	PROP. LIQ. REMAINING	=	91.02	WGT. OF PROP. VAPOR	=	20.1522
HELIUM PART.PRESSURE	= 12.120	TOTAL PRES. *PPV+PHE*	=	23.197	NOM. OPERATING PRES.	=	26.700
HELIUM FLOW RATE	= .4943-02	WEIGHT OF HELIUM USED	=	.4943+00	NEW TANK PRESSURE	=	26.700
TOTAL HELIUM CONSUMED	= 1.937						

185

NAME USERS NAME * * * * * PAGE 32
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * TIME 15:02:06
 BLD. 104 * CASE 1
 * * * * * AT4307 * * * * *
 * * * * * ACPS - TEST DEMONSTRATION PROBLEM * * * * *

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** FINAL ENGINE SHUTDOWN PROPELLANT TANK CONDITIONS *****

*** COMPUTE FINAL TANK CONDITIONS ***

FLUID CONSIDERED -	OXYGEN	FLUID TEMPERATURE	=	163.01	COAST DURATION - SEC. =	300.
WGT. OF LIQ. PROP.	= 90.226	WGT. PROP. VAPOR	=	20.942	WGT. HELIUM IN VAPOR =	1.937
PART. PRES. PROP. VAPOR	= 15.206	PART. PRES. HELIUM GAS	=	11.622	CURRENT TANK PRESSURE =	26.828
EFF. INTERNAL ENERGY	= -.44857398+02					
FINAL TANK TEMP.	= 163.012	TOTAL VENTED GAS WGT. =		.000	WGT. OF GAS RESIDUALS =	22.879
WGT. OF LIQ. RESIDUALS	= 90.226					

*** COMPUTE PRESSURIZATION SYSTEM WEIGHT ***

TOTAL HELIUM GAS HEAD =	1.937	WGT. PRESSURANT SYSTEM =	42.905
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NAME USERS NAME * * * * * PAGE 33
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:06
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS ***

*** INITIAL TANK CONDITIONS ***

FLUID CONSIDERED -	HYDROGEN	FLUID TEMPERATURE	=	37.05	TANK INITIAL PRESSURE	=	16.00
WGT. OF LIQ. PROP.	= 1948.20	WGT. PROP. VAPOR	=	1.204	WGT. LIQ. + VAPOR	=	1949.40
WGT. HELIUM IN VAPOR	= .00	TOTAL FLUIDS IN TANK	=	1949.40	VOL. OF LIQUID FLUID	=	439.63
PART. PRES. PROP. VAPOR	= 16.000	PART. PRES. HELIUM GAS	=	.000	ULLAGE VOLUME IN TANK	=	13.43
TANK VOLUME	= 453.06	EFF. TANK DENSITY	=	4.303	EFF. INTERNAL ENERGY	=	-.11041192+03

***** COAST NUMBER = 1 PRESS. SYS. NO. = 0 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	HYDROGEN	FLUID TEMPERATURE	=	37.95	COAST DURATION - SEC.	=	540.
WGT. OF LIQ. PROP.	= 1948.037	WGT. PROP. VAPOR	=	1.365	WGT. HELIUM IN VAPOR	=	.000
PART. PRES. PROP. VAPOR	= 18.365	PART. PRES. HELIUM GAS	=	.000	CURRENT TANK PRESSURE	=	18.365
EFF. INTERNAL ENERGY	= -.11040295+03						

***** BURN NUMBER = 1 PRESS. SYS. NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	HYDROGEN	BURN DURATION - SEC.	=	5.	FLOWRATE FOR THRUST	=	2.498
THRUST PROP. REMAINING	= 1066.76	PROPELLANT IN TANK	=	1940.20	EFF. INTERNAL ENERGY	=	-.11040295+03
EFF. TANK ENERGY	= -.21299417+06				TOTAL FLOWRATE	=	4.561

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 20.890	TOTAL FLUIDS IN TANK	=	1928.51	PROPELLANT LIQ. + VAP.	=	1928.51
THRUST PROP. REMAINING	= 1055.32	NEW EFF. TANK DENSITY	=	4.2566	PART. PRES. PROP. VAPOR	=	17.366
NEW INTERNAL ENERGY	= -.11044483+03						

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 37.58	STORED HELIUM TEMP.	=	40.00	NEW TANK ULLAGE VOL.	=	16.385
NEW PROP. LIQ. VOLUME	= 436.67	PROP. LIQ. REMAINING	=	1926.93	WGT. OF PROP. VAPOR	=	1.5824
HELIUM PART. PRESSURE	= 1.734	TOTAL PRES. *PPV+PHE*	=	17.366	NOM. OPERATING PRES.	=	19.100
HELIUM FLOW RATE	= .5777-01	WEIGHT OF HELIUM USED	=	.2646+00	NEW TANK PRESSURE	=	19.100
TOTAL HELIUM CONSUMED	= .265						

NAME USERS NAME * * * * * PAGE 34
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:06
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 2 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	HYDROGEN	FLUID TEMPERATURE	=	38.56	COAST DURATION - SEC. =	.7975.
WGT.OF LIQ. PROP.	= 1926.778	WGT. PROP. VAPOR	=	1.734	WGT.HELIUM IN VAPOR =	.265
PART.PRES.PROP.VAPOR	= 19.267	PART.PRES.HELIUM GAS	=	1.671	CURRENT TANK PRESSURE =	20.938
EFF.INTERNAL ENERGY	= -.11031090+03					

***** BURN NUMBER = 2 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	HYDROGEN	BURN DURATION - SEC. =	6.	FLOWRATE FOR THRUST =	2.498
THRUST PROP.REMAINING =	1055.32	PROPELLANT IN TANK =	1928.51	EFF. INTERNAL ENERGY =	-.11031090+03
EFF. TANK ENERGY =	-.20976858+06			TOTAL FLOWRATE =	4.564

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN =	28.069	TOTAL FLUIDS IN TANK =	1900.44	PROPELLANT LIQ.+VAP. =	1900.44
THRUST PROP.REMAINING =	1039.96	NEW EFF. TANK DENSITY =	4.1947	PART.PRES.PROP.VAPOR =	17.676
NEW INTERNAL ENERGY =	-.11037879+03				

*** COMPUTE PRESSURE NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =	37.69	STORED HELIUM TEMP. =	40.00	NEW TANK ULLAGE VOL. =	22.481
NEW PROP. LIQ. VOLUME =	430.58	PROP. LIQ. REMAINING =	1898.24	WGT. OF PROP. VAPOR =	2.2065
HELIUM PART.PRESSURE =	1.424	TOTAL PRES. *FPV+PHE* =	18.867	NOM. OPERATING PRES. =	19.100
HELIUM FLOW RATE =	.5471-02	WEIGHT OF HELIUM USED =	.3365-01	NEW TANK PRESSURE =	19.100
TOTAL HELIUM CONSUMED =	.298				

NAME USERS NAME * * * * * PAGE 35
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:07
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 3 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	HYDROGEN	FLUID TEMPERATURE	=	37.84	COAST DURATION - SEC.	=	2094.
WGT.OF LIQ. PROP.	= 1898.193	WGT. PROP. VAPOR	=	2.250	WGT. HELIUM IN VAPOR	=	.298
PART.PRES.PROP.VAPOR	= 18.059	PART.PRES. HELIUM GAS	=	1.347	CURRENT TANK PRESSURE	=	19.406
EFF. INTERNAL ENERGY	= -.11034311+03						

***** BURN NUMBER = 3 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	HYDROGEN	BURN DURATION - SEC.	=	4.	FLOWRATE FOR THRUST	=	2.498
THRUST PROP. REMAINING	= 1039.96	PROPELLANT IN TANK	=	1900.44	EFF. INTERNAL ENERGY	=	-.11034311+03
EFF. TANK ENERGY	= -.20795540+06				TOTAL FLOWRATE	=	4.564

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 16.339	TOTAL FLUIDS IN TANK	=	1884.10	PROPELLANT LIQ.+VAP.	=	1884.10
THRUST PROP. REMAINING	= 1031.02	NEW EFF. TANK DENSITY	=	4.1586	PART.PRES.PROP.VAPOR	=	17.334
NEW INTERNAL ENERGY	= -.11037366+03						

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 37.57	STORED HELIUM TEMP.	=	40.00	NEW TANK ULLAGE VOL.	=	26.715
NEW PROP. LIQ. VOLUME	= 426.34	PROP. LIQ. REMAINING	=	1881.53	WGT. OF PROP. VAPOR	=	2.5757
HELIUM PART. PRESSURE	= 1.766	TOTAL PRES. *PPV+PHE*	=	18.460	NOM. OPERATING PRES.	=	19.100
HELIUM FLOW RATE	= .3943-01	WEIGHT OF HELIUM USED	=	.1412+00	NEW TANK PRESSURE	=	19.100
TOTAL HELIUM CONSUMED	= .439						

NAME USERS NAME * * * * * PAGE 36
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:07
 BLD. 104 * AT4307 * CASE 1
 * * * * * ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 4 PRESS.SYS.NO. = 2 *****

*** PRE- OF NON-VENT CONDITIONS ***

FLUID CONSIDERED -	HYDROGEN	FLUID TEMPERATURE	=	37.61	COAST DURATION - SEC.	=	536.
WGT.OF LIQ. PROP.	= 1881.512	WGT. PROP. VAPOR	=	2.591	WGT. HELIUM IN VAPOR	=	.439
PART.PRES.PROP.VAPOR	= 17.449	PART.PRES. HELIUM GAS	=	1.660	CURRENT TANK PRESSURE	=	19.110
EFF. INTERNAL ENERGY	= -.11036445+03						

***** BURN NUMBER = 4 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	HYDROGEN	BURN DURATION - SEC.	=	39.	FLOWRATE FOR THRUST	=	2.498
THRUST PROP. REMAINING	= 1031.02	PROPELLANT IN TANK	=	1884.10	EFF. INTERNAL ENERGY	=	-.11036445+03
EFF. TANK ENERGY	= -.18892080+06				TOTAL FLOWRATE	=	4.564

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 177.087	TOTAL FLUIDS IN TANK	=	1707.02	PROPELLANT LIQ.+VAP.	=	1707.02
THRUST PROP. REMAINING	= 934.12	NEW EFF. TANK DENSITY	=	3.7678	PART.PRES.PROP.VAPOR	=	14.841
NEW INTERNAL ENERGY	= -.11067308+03						

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 36.57	STORED HELIUM TEMP.	=	40.00	NEW TANK ULLAGE VOL.	=	70.609
NEW PROP. LIQ. VOLUME	= 382.45	PROP. LIQ. REMAINING	=	1701.11	WGT. OF PROP. VAPOR	=	5.8096
HELIUM PART. PRESSURE	= 4.259	TOTAL PRES. *PPV+PHE*	=	15.452	NOM. OPERATING PRES.	=	19.100
HELIUM FLOW RATE	= .6082-01	WEIGHT OF HELIUM USED	=	.2360+01	NEW TANK PRESSURE	=	19.100
TOTAL HELIUM CONSUMED	= 2.799						

NAME USERS NAME * * * * * PAGE 37
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:07
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 5 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	HYDROGEN	FLUID TEMPERATURE	=	36.62	COAST DURATION - SEC. =	2061.
WGT.OF LIQ. PROP.	= 1701.064	WGT. PROP. VAPOR	=	5.953	WGT. HELIUM IN VAPOR =	2.799
PART.PRES.PROP.VAPOR	= 14.962	PART.PRES. HELIUM GAS	=	3.899	CURRENT TANK PRESSURE =	18.860
EFF. INTERNAL ENERGY	= -.11063398+03					

***** BURN NUMBER = 5 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	HYDROGEN	BURN DURATION - SEC.	=	7.	FLOWRATE FOR THRUST	=	2.498
THRUST PROP. REMAINING	= 934.12	PROPELLANT IN TANK	=	1707.02	EFF. INTERNAL ENERGY	=	-.11063398+03
EFF. TANK ENERGY	= -.18513058+06				TOTAL FLOWRATE	=	4.564

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 33.911	TOTAL FLUIDS IN TANK	=	1673.11	PROPELLANT LIQ.+VAP.	=	1673.11
THRUST PROP. REMAINING	= 915.56	NEW EFF. TANK DENSITY	=	3.6929	PART.PRES.PROP.VAPOR	=	14.818
NEW INTERNAL ENERGY	= -.11065086+03						

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 36.56	STORED HELIUM TEMP.	=	40.00	NEW TANK ULLAGE VOL.	=	78.406
NEW PROP. LIQ. VOLUME	= 374.65	PROP. LIQ. REMAINING	=	1666.55	WGT. OF PROP. VAPOR	=	6.5528
HELIUM PART. PRESSURE	= 4.282	TOTAL PRES. *PPV+PHE*	=	18.323	NON. OPERATING PRES.	=	19.100
HELIUM FLOW RATE	= .4390-01	WEIGHT OF HELIUM USED	=	.3262+00	NEW TANK PRESSURE	=	19.100
TOTAL HELIUM CONSUMED	= 3.125						

NAME USERS NAME * * * * * PAGE 38
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:07
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 APCS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 6 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	HYDROGEN	FLUID TEMPERATURE	=	36.57	COAST DURATION - SEC. =	593.
WGT.OF LIQ. PROP.	= 1666.543	WGT. PROP. VAPOR	=	6.562	WGT. HELIUM IN VAPOR =	3.125
PART.PRES.PROP.VAPOR	= 14.841	PART.PRES. HELIUM GAS	=	3.915	CURRENT TANK PRESSURE =	18.756
EFF. INTERNAL ENERGY	= -.11063939+03					

***** BURN NUMBER = 6 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	HYDROGEN	BURN DURATION - SEC. =	4.	FLOWRATE FOR THRUST =	2.498
THRUST PROP.REMAINING =	915.56	PROPELLANT IN TANK =	1673.11	EFF. INTERNAL ENERGY =	-.11063939+03
EFF. TANK ENERGY =	-.18331533+06			TOTAL FLOWRATE =	4.564

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN =	16.339	TOTAL FLUIDS IN TANK =	1656.77	PROPELLANT LIQ.+VAP. =	1656.77
THRUST PROP.REMAINING =	906.62	NEW EFF. TANK DENSITY =	3.6568	PART.PRES.PROP.VAPOR =	14.773
NEW INTERNAL ENERGY =	-.11064647+03				

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =	36.54	STORED HELIUM TEMP. =	40.00	NEW TANK ULLAGE VOL. =	82.200
NEW PROP. LIQ. VOLUME =	370.86	PROP. LIQ. REMAINING =	1649.92	WGT. OF PROP. VAPOR =	6.8510
HELIUM PART.PRESSURE =	4.327	TOTAL PRES. *FPV+PHE* =	16.504	NOM. OPERATING PRES. =	19.100
HELIUM FLOW RATE =	.5178-01	WEIGHT OF HELIUM USED =	.1854+00	NEW TANK PRESSURE =	19.100
TOTAL HELIUM CONSUMED =	3.311				

NAME USERS NAME * * * * * PAGE 39
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT: 30235 * * TIME 15:02:07
 BLD: 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 7 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	HYDROGEN	FLUID TEMPERATURE	=	36.55	COAST DURATION - SEC.	=	536.
WGT.OF LIQ. PROP.	= 1649.902	WGT. PROP. VAPOR	=	6.858	WGT. HELIUM IN VAPOR	=	3.311
PART.PRES.PROP.VAPOR	= 14.791	PART.PRES. HELIUM GAS	=	3.953	CURRENT TANK PRESSURE	=	18.744
EFF. INTERNAL ENERGY	= -.11063599+03						

***** BURN NUMBER = 7 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	HYDROGEN	BURN DURATION - SEC.	=	66.	FLOWRATE FOR THRUST	=	2.498
THRUST PROP.REMAINING	= 906.62	PROPELLANT IN TANK	=	1656.77	EFF. INTERNAL ENERGY	=	-.11063599+03
EFF. TANK ENERGY	= -.15012108+06				TOTAL FLOWRATE	=	4.564

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 301.686	TOTAL FLUIDS IN TANK	=	1355.08	PROPELLANT LIQ.+VAP.	=	1355.08
THRUST PROP.REMAINING	= 741.53	NEW EFF. TANK DENSITY	=	2.9910	PART.PRES.PROP.VAPOR	=	13.513
NEW INTERNAL ENERGY	= -.11078394+03						

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 36.00	STORED HELIUM TEMP.	=	40.00	NEW TANK ULLAGE VOL.	=	152.365
NEW PROP. LIQ. VOLUME	= 300.69	PROP. LIQ. REMAINING	=	1343.37	WGT. OF PROP. VAPOR	=	11.7113
HELIUM PART.PRESSURE	= 5.587	TOTAL PRES. *PPV+PHE*	=	15.613	NOM. OPERATING PRES.	=	19.100
HELIUM FLOW RATE	= .6976-01	WEIGHT OF HELIUM USED	=	.4611+01	NEW TANK PRESSURE	=	19.100
TOTAL HELIUM CONSUMED	= 7.922						

NAME USERS NAME * * * * * PAGE 40
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:08
 BLD. 104 * AT4307 * CASE J
 * * * * * ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 8 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	HYDROGEN	FLUID TEMPERATURE	=	36.09	COAST DURATION - SEC.	=	714.
WGT.OF LIQ. PROP.	= 1343.198	WGT. PROP. VAPOR	=	11.882	WGT. HELIUM IN VAPOR	=	7.922
PART.PRES.PROP.VAPOR	= 13.730	PART.PRES. HELIUM GAS	=	5.041	CURRENT TANK PRESSURE	=	18.771
EFF. INTERNAL ENERGY	= -.11076687+03						

***** BURN NUMBER = 8 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	HYDROGEN	BURN DURATION - SEC.	=	32.	FLOWRATE FOR THRUST	=	2.498
THRUST PROP. REMAINING	= 741.53	PROPELLANT IN TANK	=	1355.08	EFF. INTERNAL ENERGY	=	-.11076687+03
EFF. TANK ENERGY	= -.13372769+06				TOTAL FLOWRATE	=	4.564

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 147.420	TOTAL FLUIDS IN TANK	=	1207.66	PROPELLANT LIQ.+VAP.	=	1207.66
THRUST PROP. REMAINING	= 660.86	NEW EFF. TANK DENSITY	=	2.6656	PART.PRES.PROP.VAPOR	=	12.991
NEW INTERNAL ENERGY	= -.11073291+03						

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 35.76	STORED HELIUM TEMP.	=	40.00	NEW TANK ULLAGE VOL.	=	186.312
NEW PROP. LIQ. VOLUME	= 266.75	PROP. LIQ. REMAINING	=	1193.84	WGT. OF PROP. VAPOR	=	13.8188
HELIUM PART.PRESSURE	= 6.109	TOTAL PRES. *PPV+PHE*	=	17.075	NOM. OPERATING PRES.	=	19.100
HELIUM FLOW RATE	= .8258-01	WEIGHT OF HELIUM USED	=	.2667+01	NEW TANK PRESSURE	=	19.100
TOTAL HELIUM CONSUMED	= 10.589						

194

LOCKHEED MISSILES & SPACE COMPANY

LMSC-A991396

NAME USERS NAME * * * * * PAGE 41
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:08
 SLD. 104 * AT4307 * CASE 1
 * * * * *
 APCS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 9 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	HYDROGEN	FLUID TEMPERATURE	=	35.32	COAST DURATION - SEC.	=	568.
WGT.OF LIQ. PROP.	= 1193.713	WGT. PROP. VAPOR	=	13.947	WGT. HELIUM IN VAPOR	=	10.589
PART.PRES.PROP.VAPOR	= 13.124	PART.PRES. HELIUM GAS	=	5.469	CURRENT TANK PRESSURE	=	18.593
EFF. INTERNAL ENERGY	= -.11071768+03						

***** BURN NUMBER = 9 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	HYDROGEN	BURN DURATION - SEC.	=	104.	FLOWRATE FOR THRUST	=	2.498
THRUST PROP. REMAINING	= 660.86	PROPELLANT IN TANK	=	1207.66	EFF. INTERNAL ENERGY	=	-.11071768+03
EFF. TANK ENERGY	= -.80652389+05				TOTAL FLOWRATE	=	4.564

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 475.122	TOTAL FLUIDS IN TANK	=	732.54	PROPELLANT LIQ.+VAP.	=	732.54
THRUST PROP. REMAINING	= 400.86	NEW EFF. TANK DENSITY	=	1.6169	PART.PRES.PROP.VAPOR	=	11.072
NEW INTERNAL ENERGY	= -.11009992+03						

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 34.83	STORED HELIUM TEMP.	=	40.00	NEW TANK ULLAGE VOL.	=	294.714
NEW PROP. LIQ. VOLUME	= 158.35	PROP. LIQ. REMAINING	=	713.62	WGT. OF PROP. VAPOR	=	18.9178
HELIUM PART.PRESSURE	= 8.028	TOTAL PRES. *PPV+PHE*	=	14.433	NOM. OPERATING PRES.	=	19.100
HELIUM FLOW RATE	= .1096+00	WEIGHT OF HELIUM USED	=	.1141+02	NEW TANK PRESSURE	=	19.100
TOTAL HELIUM CONSUMED	= 22.001						

195

NAME USERS NAME * * * * * PAGE 42
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:09
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 10 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	HYDROGEN	FLUID TEMPERATURE	=	35.14	COAST DURATION - SEC. =	1876.
WGT.OF LIQ. PROP.	= 712.672	WGT. PROP. VAPOR	=	19.866	WGT. HELIUM IN VAPOR =	22.001
PART.PRES.PROP.VAPOR	= 11.689	PART.PRES. HELIUM GAS	=	7.050	CURRENT TANK PRESSURE =	18.739
EFF. INTERNAL ENERGY	= -.11001698+03					

***** BURN NUMBER = 10 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	HYDROGEN	BURN DURATION - SEC. =	32.	FLOWRATE FOR THRUST =	2.498
THRUST PROP. REMAINING =	400.86	PROPELLANT IN TANK =	732.54	EFF. INTERNAL ENERGY =	-.11001698+03
EFF. TANK ENERGY =	-.64112928+05			TOTAL FLOWRATE =	4.564

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN =	145.594	TOTAL FLUIDS IN TANK =	566.94	PROPELLANT LIQ.+VAP. =	566.94
THRUST PROP. REMAINING =	321.19	NEW EFF. TANK DENSITY =	1.2955	PART.PRES.PROP.VAPOR =	11.374
NEW INTERNAL ENERGY =	-.10923182+03				

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE =	34.98	STORED HELIUM TEMP. =	40.00	NEW TANK ULLAGE VOL. =	327.458
NEW PROP. LIQ. VOLUME =	125.60	PROP. LIQ. REMAINING =	565.41	WGT. OF PROP. VAPOR =	21.5356
HELIUM PART. PRESSURE =	7.726	TOTAL PRES. *CPV+PHE* =	17.689	NOM. OPERATING PRES. =	19.100
HELIUM FLOW RATE =	.4791-01	WEIGHT OF HELIUM USED =	.1528+01	NEW TANK PRESSURE =	19.100
TOTAL HELIUM CONSUMED =	23.529				

NAME USERS NAME * * * * * PAGE 43
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:09
 BLD. 104 * AT4307 * CASE 1
 * * * * * ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 11 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	HYDROGEN	FLUID TEMPERATURE	=	43.03	COAST DURATION - SEC.	=	571048.
WGT.OF LIQ. PROP.	= 522.176	WGT. PROP. VAPOR	=	64.768	WGT. HELIUM IN VAPOR	=	23.529
PART. PRES. PROP. VAPOR	= 37.502	PART. PRES. HELIUM GAS	=	6.313	CURRENT TANK PRESSURE	=	45.816
EFF. INTERNAL ENERGY	= -77723276+02						

*** POST VENT CONDITIONS ***

TANK VENT PRESSURE	= 24.10	WGT. VENTED FLUIDS	=	54.91	WGT. OF LIQ. IN TANK	=	495.18
WGT. VAPOR IN TANK	= 36.853	WGT. HELIUM IN VAPOR	=	13.105	TOTAL FLUIDS IN TANK	=	545.14
PART. PRES. PROP. VAPOR	= 19.762	PART. PRES. HELIUM GAS	=	4.338	VENTED TANK PRESSURE	=	24.100
EFF. INTERNAL ENERGY	= -94977942+02						

***** BURN NUMBER = 11 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	HYDROGEN	BURN DURATION - SEC.	=	16.	FLOWRATE FOR THRUST	=	2.498
THRUST PROP. REMAINING	= 321.19	PROPELLANT IN TANK	=	495.18	EFF. INTERNAL ENERGY	=	-94977942+02
EFF. TANK ENERGY	= -45225773+05				TOTAL FLOWRATE	=	3.851

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 62.225	TOTAL FLUIDS IN TANK	=	462.91	PROPELLANT LIQ.+VAP.	=	469.81
THRUST PROP. REMAINING	= 280.83	NEW EFF. TANK DENSITY	=	1.0370	PART. PRES. PROP. VAPOR	=	20.339
NEW INTERNAL ENERGY	= -93651651+02						

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 38.89	STORED HELIUM TEMP.	=	40.00	NEW TANK ULLAGE VOL.	=	354.452
NEW PROP. LIQ. VOLUME	= 98.61	PROP. LIQ. REMAINING	=	430.36	WGT. OF PROP. VAPOR	=	39.4450
HELIUM PART. PRESSURE	= 3.862	TOTAL PRES. *PPV+PHE*	=	24.201	NOM. OPERATING PRES.	=	19.100
HELIUM FLOW RATE	= .0000	WEIGHT OF HELIUM USED	=	.0000	NEW TANK PRESSURE	=	24.201
TOTAL HELIUM CONSUMED	= 23.529						

NAME USERS NAME * * * * * PAGE 44
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:09
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** COAST NUMBER = 12 PRESS.SYS.NO. = 2 *****

*** PRE- OR NON-VENT CONDITIONS ***

FLUID CONSIDERED -	HYDROGEN	FLUID TEMPERATURE	=	39.03	COAST DURATION - SEC. =	9584.
WGT.OF LIQ. PROP.	= 429.512	WGT. PROP. VAPOR	=	40.298	WGT. HELIUM IN VAPOR =	13.105
PART.PRES.PROP.VAPOR	= 20.813	PART.PRES. HELIUM GAS	=	3.875	CURRENT TANK PRESSURE =	24.688
EFF. INTERNAL ENERGY	= -.92990993+02					

*** POST VENT CONDITIONS ***

TANK VENT PRESSURE	= 24.10	WGT. VENTED FLUIDS	=	1.40	WGT.OF LIQ. IN TANK	= 428.93
WGT. VAPOR IN TANK	= 39.484	WGT. HELIUM IN VAPOR	=	12.654	TOTAL FLUIDS IN TANK	= 461.07
PART.PRES.PROP.VAPOR	= 20.317	PART.PRES. HELIUM GAS	=	3.783	VENTED TANK PRESSURE	= 24.100
EFF. INTERNAL ENERGY	= -.93436532+02					

***** BURN NUMBER = 12 PRESS.SYS.NO. = 2 *****

*** COMPUTE ENERGY BALANCE FOR BURN ***

FLUID CONSIDERED -	HYDROGEN	BURN DURATION - SEC.	=	100.	FLOWRATE FOR THRUST	= 2.498
THRUST PROP. REMAINING	= 280.83	PROPELLANT IN TANK	=	428.93	EFF. INTERNAL ENERGY	= -.93436532+02
EFF. TANK ENERGY	= -.49783530+04				TOTAL FLOWRATE	= 3.815

*** COMPUTE RESULTING TANK CONDITIONS ***

PROPELLANT WITHDRAWN	= 381.474	TOTAL FLUIDS IN TANK	=	99.59	PROPELLANT LIQ.+VAP.	= 86.94
THRUST PROP. REMAINING	= 31.07	NEW EFF. TANK DENSITY	=	.1919	PART.PRES.PROP.VAPOR	= 17.623
NEW INTERNAL ENERGY	= -.49986179+02					

*** COMPUTE PRESSURANT NEEDED FOR THIS BURN ***

TANK LIQ. TEMPERATURE	= 37.67	STORED HELIUM TEMP.	=	40.00	NEW TANK ULLAGE VOL.	= 443.180
NEW PROP. LIQ. VOLUME	= 9.88	PROP. LIQ. REMAINING	=	43.56	WGT. OF PROP. VAPOR	= 43.3789
HELIUM PART. PRESSURE	= 2.888	TOTAL PRES. *PPV+PHE*	=	20.512	NON. OPERATING PRES.	= 19.100
HELIUM FLOW RATE	= .0000	WEIGHT OF HELIUM USED	=	.0000	NEW TANK PRESSURE	= 20.512
TOTAL HELIUM CONSUMED	= 23.529					

NAME USERS NAME * * * * * PAGE 45
 CEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:09
 ELD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** TANK AND VENT PARAMETER CALCULATIONS - CONTD. ***

***** FINAL ENGINE SHUTDOWN PROPELLANT TANK CONDITIONS *****

*** COMPUTE FINAL TANK CONDITIONS ***

FLUID CONSIDERED -	HYDROGEN	FLUID TEMPERATURE	=	37.68	COAST DURATION - SEC. =	300.
WGT. OF LIQ. PROP.	= 43.505	WGT. PROP. VAPOR	=	43.436	WGT. HELIUM IN VAPOR =	12.654
PART. PRES. PROP. VAPOR	= 17.649	PART. PRES. HELIUM GAS	=	2.889	CURRENT TANK PRESSURE =	20.537
EFF. INTERNAL ENERGY	= -.49874429+02					
FINAL TANK TEMP.	= 37.684	TOTAL VENTED GAS WGT.	=	56.304	WGT. OF GAS RESIDUALS =	56.090
WGT. OF LIQ. RESIDUALS	= 43.505					

*** COMPUTE PRESSURIZATION SYSTEM WEIGHT ***

TOTAL HELIUM GAS REQD =	23.529	WGT. PRESSURANT SYSTEM =	75.294
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NAME USERS NAME * * * * * PAGE 46
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:10
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** FINAL TANK SIZING CALCULATIONS ***

	OXYGEN	HYDROGEN
NUMBER OF TANKS	1	1
MATERIAL TYPE	2	2
INSULATION TYPE	2	2
FLUID WGT. (TOTAL)	.543008+04	.225820+04
FLUID VOLUME /TANK	.766785+02	.509397+03
HGT ADDED CYL SECT	.544434+00	.234124+02
DIAMETER (FT)/TANK	.506600+01	.500000+01
SURFACE AREA /TANK	.892918+02	.446301+03
TANK VOLUME / TANK	.790500+02	.525151+03
TANK HGT. (LB) TOT	.448476+02	.221240+03
INSUL. THICKNESS	.200000+01	.200000+01
INSUL. WT (LB) TOT	.364608+02	.182240+03

NAME USERS NAME * * * * * PAGE 47
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:10
 BLD. 104 * AT4307 * CASE 1
 * * * * *
 ACPS - TEST DEMONSTRATION PROBLEM

*** ACCUMULATOR SIZING CALCULATIONS ***

	OXYGEN	HYDROGEN
NUMBER OF TANKS	1	1
MATERIAL TYPE	1	1
INSULATION TYPE	4	4
HGT ADDED CYL SECT	.000000	.000000
DIAMETER (FT)/TANK	.168389+01	.517344+01
SURFACE AREA /TANK	.890794+01	.840832+02
TANK VOLUME / TANK	.250000+01	.725000+02
TANK WGT. (LB) TOT	.347921+02	.100850+04
INSUL. THICKNESS	.200000+01	.200000+01
INSUL. WT (LB) TOT	.124117+01	.117156+02
GAS RESIDUALS WT.	.683188+02	.695175+02

NAME USERS NAME * * * * * PAGE 48
DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
EXT. 30235 * TIME 15:02:10
BLD. 104 * AT4307 * CASE 1
* * * * *
ACPS - TEST DEMONSTRATION PROBLEM

*** TANK PROPELLANT ACQUISITION DEVICE COMPUTATION***

	OXYGEN	HYDROGEN
TYPE ACQ. DEVICE	SURF TENSION	SURF TENSION
DEVICE WT. (LBS)	.190053+02	.751981+02
TRAPPED BY DEVICE	.112225+03	.435049+02
RESID. PROPELLANT	.902258+02	.435049+02

NAME USERS NAME * * * * * PAGE 49
 DEPT 6213 * THE INTEGRATED MATH MODEL * DATE 17 APR 73
 EXT. 30235 * * TIME 15:02:10
 BLD. 104 * AT4307 * CASE 1
 * * * * *

ACPS - TEST DEMONSTRATION PROBLEM

*** COMPONENT WEIGHT SUMMARY ***

... OXIDIZER ...

COMPONENT	CODE	COMPONENT WT. (LBS)	INSULATION WT. (LBS)
LINE	LN01	4.009	.188
TEE	FT01	.433	.000
LINE	LN02	5.466	.256
TAP	FT02	.342	.000
LINE	LN03	.875	.041
VALVE	IV01	6.314	.000
LINE	LN04	.437	.021
VALVE	CV02	4.406	.000
LINE	LN05	1.458	.068
TAP	FT03	.342	.000
LINE	LN06	.729	.034
REG	PR01	9.630	.000
LINE	LN07	1.913	.051
ACCUM	AC01	34.792	1.241
LINE	LN08	1.531	.041
HEX	HX01	22.655	.000
LINE	LN09	.383	.011
VALVE	CV01	9.000	.000
LINE	LN10	.383	.011
PUMP	HP01	73.362	.000
LINE	LN11	4.373	.213
VALVE	SV01	4.142	.000
LINE	LN12	.547	.025
TAP	FT04	.534	.000
LINE	LN13	1.093	.050
TANK	TK01	63.853	36.461

... FUEL ...

COMPONENT	CODE	COMPONENT WT. (LBS)	INSULATION WT. (LBS)
LINE	LN21	3.508	.920
TEE	FT21	.331	.000
LINE	LN22	4.783	1.254
TAP	FT22	.262	.000
LINE	LN23	.765	.201
VALVE	IV02	6.121	.000
LINE	LN24	.383	.100
VALVE	CV04	4.255	.000
LINE	LN25	1.275	.334
TAP	FT23	.262	.000
LINE	LN26	.638	.167
REG	PR02	9.392	.000
LINE	LN27	1.674	.251
ACCUM	AC02	1008.496	11.716
LINE	LN28	1.148	.182
HEX	HX03	61.123	.000
LINE	LN29	.574	.091
VALVE	CV03	9.214	.000
LINE	LN30	.574	.091
PUMP	HP02	34.569	.000
LINE	LN31	4.373	1.094
VALVE	SV02	4.406	.000
LINE	LN32	.437	.109
TAP	FT24	.342	.000
LINE	LN33	.875	.219
TANK	TK02	296.438	182.240

*** COMPONENT WEIGHT SUMMARY TOTALS ***

CONSUMER WEIGHT - LBS	.159375+03
OXIDIZER SYSTEM WT. -LBS	.253000+03
OXID INSULATION WT - LBS	.387139+02
FUEL SYSTEM WT. - LBS	.145622+04
FUEL INSULATION WT - LBS	.198969+03
TOTAL SYSTEM WT. - LBS	.210628+04

Section 3 REFERENCES

- 1.0 External Pressurization Systems for Cryogenic Storage System,
AR-71-7535, Design Reference Manual, AiResearch Mfg Co. ,
10 Sept 1971 (Section 6)

- 1.4-1 UNIVAC 1100 Series Systems, Manual UP-4144 (Rev 2), Section 10.2 –
COLLECTOR Processor, Sperry-Rang Corporation.

- 2.1-1 "Shuttle Cryogenic Supply System Optimization Study," Interim Report,
Volume II, Section 9, ACPS; Contract NAS 9-11330, LMSC-SS-1109,
15 Dec 1971